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S. Department
Transportation

Transportation Energy Management

Transit Operator Facilities
Volume II: Field Guide

September 1982

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September 1982

Prepared by

Municipality of Metropolitan Seattle

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September 1982

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INTRODUCTION

The **Field Guide** is the second part of the **Energy Conservation Handbook.** Together with the **Office Guide,** the **Field Guide** provides step-by-step instructions for developing an energy conservation program for transit facilities. Because this part of the handbook focuses on data collection and on-site surveys, it has been published separately. Also included in the **Field Guide** are technical reference materials and a case study as appendices.

The **Field Guide** focuses on Steps 2 and 3 of the conservation program, as outlined in Figure One. Step 2 provides the instructions and necessary focus for collecting baseline data on a building's energy use, while Step 3 includes a checklist for conducting an on-site evaluation of the building's energy systems. Refer to the **Office Guide** for a general discussion of the entire conservation program and for specific instructions for the other steps.

FIGURE 1: STEPS TO ENERGY CONSERVATION

STEP 1	**ENERGY CONSERVATION TEAM**	Organize a team of managers, supervisors and operating and maintenance staff and obtain technical and organizational support.
STEP 2	**ENERGY PROFILE**	Determine the overall energy consumption for the facility.
STEP 3	**WALK-THROUGH SURVEY**	Evaluate the existing energy efficiency of the facility and identify appropriate changes in maintenance and operating procedures.
STEP 4	**NO-COST/LOW-COST OPERATION AND MAINTENANCE (O & M) ACTIONS**	Modify operating and maintenance procedures and implement other no-cost/low-cost conservation actions.
STEP 5	**ENERGY CONSERVATION MEASURES (ECMs)**	Determine potential energy savings and implementation costs of capital intensive energy conservation measures and implement the most cost-effective ones.
STEP 6	**PERMANENT ENERGY CONSERVATION PROGRAM**	Establish on-going monitoring of energy use and development and implement an employee energy awareness program.

DEVELOP AN ENERGY PROFILE (STEP 2)

The major purpose of an energy profile is to develop an accurate picture of how energy is used in the building. This information provides a solid foundation for the conservation program and establishes a baseline for energy consumption, by which the effects of conservation activities can be measured. These baseline data will also serve as a standard for identifying fluctuation in consumption that may indicate a problem in the building's energy efficiency, providing that the fluctuation is not a result of unusual operating conditions by extremes in weather conditions.

Determining the historic energy consumption of a facility is the basic element of a building's energy profile. This task involves reviewing the utility and fuel bills for electricity, natural gas, heating oil, purchased steam and other types of energy used in the building.

Energy Profile Worksheets have been developed for collecting this information. Sample worksheets and instructions for completing them follow. Refer to the energy conservation case study (Appendix D) for examples of completed worksheets.

Energy Profile Worksheets 1A Through 1D

To complete Worksheets 1A through 1D, it is necessary to obtain fuel and utility bills for at least the past 12 months. This time span will establish a **base period** for comparing future energy consumption data. However, in order to have a more accurate picture of typical energy use, a base period of two to three years is preferable, especially if the past year was characterized by extreme weather conditions. If fuel or utility bills are not available, the local utility can be contacted for replacement copies. Most utilities will be willing to provide a record of energy consumption and costs.

Referring to the appropriate bills for each energy source, enter the units of energy consumed, e.g., therms of natural gas or kilowatts of electricity, and the costs for each month. Since a standard measure is required to produce a total of all energy used, conversion factors for translating therms, kilowatts and other units of energy into MBTUs (millions of BTUs) are provided on each worksheet.

ENERGY PROFILE WORKSHEET 1-A

Electricity

Building_____Year_____

Month	$ Amount	KWH	×3413=BTUs	÷1,000,000=Million BTUs
January				
February				
March				
April				
May				
June				
July				
August				
September				
October				
November				
December				
Annual Totals				

ENERGY PROFILE WORKSHEET 1-B

Gas

Building_____Year_____

Month	$ Amount	Therms	×100,000=BTUs	÷1,000,000=MBTUs
January				
February				
March				
April				
May				
June				
July				
August				
September				
October				
November				
December				
Annual Totals				

ENERGY PROFILE WORKSHEET 1-C

Oil

Building _____ Year _____

Month	$ Amount	Gallons	×140,000 (#2) 160,000 (#6) =BTUs	÷1,000,000=MBTUs
January				
February				
March				
April				
May				
June				
July				
August				
September				
October				
November				
December				
Annual Totals				

ENERGY PROFILE WORKSHEET 1-D

Steam

Building _____ Year _____

Month	$ Amount	Pounds	×1,000=BTUs	÷1,000,000=MBTUs
January				
February				
March				
April				
May				
June				
July				
August				
September				
October				
November				
December				
Annual Totals				

Energy Profile Worksheets 2-A Through 2-C

Once worksheets 1A through 1D have been completed, the combined total of energy used in the facility can be calculated on worksheet 2A. This sum will represent the composite energy use from all sources for each month. Then, working from the completed worksheets for each year in the base period, worksheet 2B can be filled in to provide a quick overview of energy use for the base period. The information on worksheet 2-B can then be compared to current month-by-month energy use.

Worksheet 2-C is designed for those transit systems with more than one facility. It provides a standard unit of energy use, the **Energy Utilization Index** (EUI), by which energy consumption in one facility can be compared with others. The EUI is calculated by dividing the total energy used in a facility (worksheet 2B) by the gross square feet of the building's floor area, thus showing the MBTUs consumed per square foot in the building. Refer to building plans to determine the gross square footage of the building. In making this calculation, include all the floor area within the building, excluding areas that are neither heated nor cooled.

ENERGY PROFILE WORKSHEET 2-A

Annual Energy Use

Building_____ Year_____

Month	MBTUs Steam	MBTUs Gas	MBTUs Oil	MBTUs Elec.	Total MBTUs
January					
February					
March					
April					
May					
June					
July					
August					
September					
October					
November					
December					
Annual Totals					

ENERGY PROFILE WORKSHEET 2-B

Energy Use Summary (in MBTUs)

Building_____

Month	19____	19____	19____	19____
January				
February				
March				
April				
May				
June				
July				
August				
September				
October				
November				
December				
Annual Totals				

ENERGY PROFILE WORKSHEET 2-C

EUI (Energy Utilization Index) Summary (in MBTUs/sq ft)

Building_____ Area in Square Feet_____

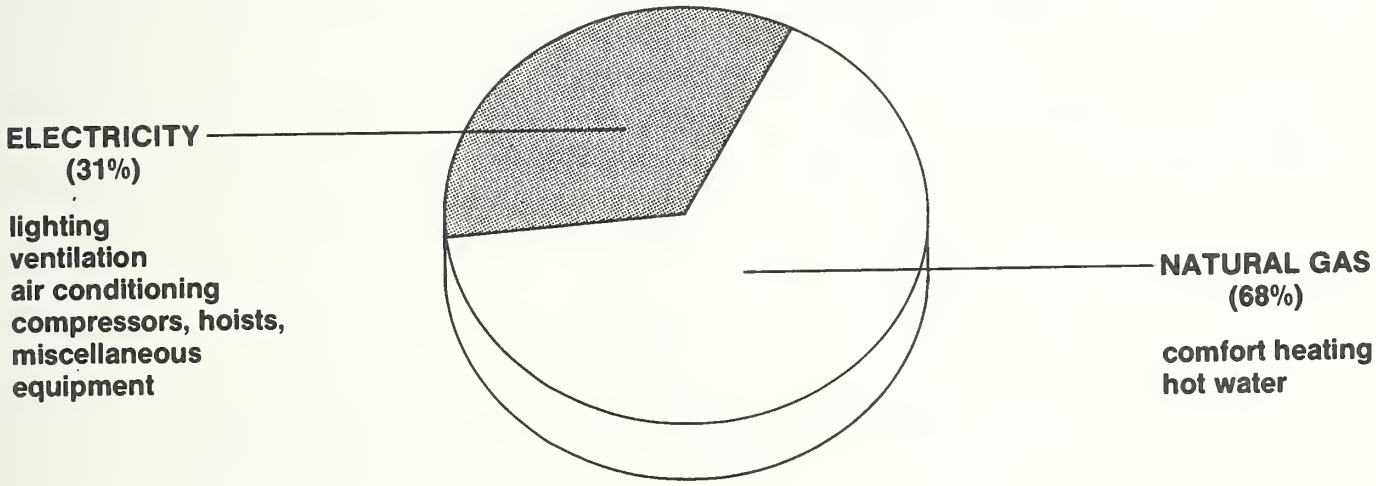
Month	19____	19____	19____	19____
January				
February				
March				
April				
May				
June				
July				
August				
September				
October				
November				
December				
Annual Totals				

Energy Profile Worksheet 3-A

Energy profile worksheet 3-A provides information about the proportion of the total energy used by each energy source. It also shows the major functions served by each source. For example, worksheet 3-A will show what proportion of the building's total energy requirements is provided by electricity and what major functions are served by electricity, such as lighting, exhaust fans and compressors. The proportion of energy used by each source can be calculated from worksheet 2-A; the functions served by each source can be determined from observation and discussions with operating and maintenance personnel. This information can also be graphically represented on a pie chart, as shown in Figure 2.

Note that Appendix C provides forms and instructions for estimating energy use by function; that is, the energy required by the lighting system or for ventilation equipment. The calculations for making such estimates can be highly complex and technical. They are not required for a conservation program that focuses on no-cost/low-cost conservation measures. However, they are required for conservation programs that include capital intensive retrofit projects.

FIGURE 2: ENERGY USE BY SOURCE



Proportion of Energy Use By Source

Building _____

Year _____ Total Annual Energy used _____ MBTU

ELECTRICITY	NATURAL GAS
Proportion of Total _____%	Proportion of Total _____%
ENERGY USES:	ENERGY USES:
1.	1.
2.	2.
3.	3.
4.	4.
5.	5.
OIL	**PURCHASED STEAM**
Proportion of Total _____%	Proportion of Total _____%
ENERGY USES:	ENERGY USES:
1.	1.
2.	2.
3.	3.
4.	4.
5.	5.

An Ongoing Task

In completing energy profile worksheets 1A through 3-A, it is important to remember that collecting this basic energy consumption data is a routine but vital activity of the conservation program. Thus, it is a good idea to assign responsibility for this task and to establish procedures for routinely tracking energy consumption. Consideration should also be given to providing this information to employees so they can keep track of how the conservation program is reducing energy use. A graphic display posted on bulletin boards or in other prominent locations is one way to keep employees informed.

CONDUCT A WALK-THROUGH SURVEY (STEP 3)

This step of the conservation program involves an on-site evaluation of the building's energy systems. The goal of the walk-through survey is twofold: to familiarize the conservation team with the facility and to identify both problem areas and corrective actions. For example, a check of the lighting system might show decreased lighting levels due to dirty fixtures, a problem that could be corrected by more frequent cleaning. Similarly, the survey could reveal excessive use of outside or make-up air, which could be corrected by reducing the volume of outside air intake.

For the most part, such corrective measure involve no-cost changes in operating and maintenance (O & M) procedures or low-cost actions that can be completed by maintenance personnel, like installation of weather stripping. These no-cost/low-cost measures should be considered before more costly, capital intensive actions are evaluated and implemented.

The basic tool for the survey is the energy survey checklist, which is divided into seven categories:

- **Administration,** or the manner in which the building's energy is used, including thermostat settings, hours of HVAC operation, maintenance and inspection procedures and similar energy management policies.

- **Lighting,** such as use of the most efficient lighting sources, cleaning of fixtures and optimal use of natural lighting.

- **Building Envelope,** including heat gain in the summer and heat loss in the winter due to infiltration through cracks, around windows and doors and transmission through exterior walls, windows and doors.

- **Ventilation,** or the exchange of inside air for fresh outside air through exhaust fans and the HVAC system.

- **Heating,** including the furnace, boiler, heat pump or other means of producing heat and the distribution system for maintaining a given comfort level in the building.

- **Cooling,** including the compressor, coils and distribution system.

- **Water,** or the hot water heater and distribution system for providing domestic hot water.

The energy survey checklist can be completed in a few hours by the conservation team. Before actually conducting the survey, it is a good idea for the team members to spend an hour or two reviewing the building's design documents and architectural plans so that everyone is familiar with the building's operation. Moreover, in order to have first-hand knowledge of how the various energy systems are operated, it is vital to have the building's operating and maintenance staff involved in the survey. It is also a good idea to schedule two different times for the survey, so that the building's systems are checked during normal operating hours as well as at night or on the weekend when operation levels are lower or the building is unoccupied.

For ease of administration, the checklist can be reproduced and attached to clipboards. Space is provided for noting the location of each observed condition and entering other comments, such as possible retrofit options and other operating and maintenance actions that building personnel may suggest. Finally, to provide a broad overview of the conditions identified, a summary sheet is included.

ENERGY SURVEY CHECKLIST: ADMINISTRATION

YES NO A-1 Can thermostats on heating/cooling units be adjusted by building occupants?

If yes,
- o Reset thermostats to correct setting.
- o Install locking covers to prevent tampering or relocate to inaccessible area.

NOTES:

YES NO A-2 Have thermostat settings been adjusted for change in seasons?

If no,
- o Set cooling thermostat for 78°F and the heating thermostat at 65°F.
- o Alert maintenance to keep proper settings.

NOTES:

YES NO A-3 Are unoccupied or little used areas heated or cooled unnecessarily?

If yes,
- o Reduce winter thermostat settings to 55°F.
- o Where possible, turn heat or cooling system off altogether.

NOTES:

YES NO A-4 Are off-hour activities scheduled?

If no,
- o Reschedule off-hour activities.
- o Reschedule janitorial work to normal working hours.

NOTES:

YES NO A-5 Are building temperatures adjusted for unoccupied periods?

If no,
- o Reduce thermostat settings by at least 10° and shut down air conditioning units at night for weekends, holidays, other unoccupied periods.
- o Install setback and minimum-maximum temperature controls.

NOTES:

YES NO A-6 Is heating/cooling equipment operated in lobbies, corridors and other public places?

If yes,
- o Close supply ducts and radiators and/or reduce thermostat settings by at least 10°.
- o Close air conditioning supply ducts serving these areas.

NOTES:

YES NO A-7 Is heating/cooling equipment started before occupants arrive and/or operated during last hour of occupancy?

If yes,
- o Schedule use of equipment based on actual need.
- o Reduce or turn off heating/cooling during last hour of occupancy, allowing the building to "coast."

NOTES:

YES NO A-8 Does use of equipment that is not required at a specific time coincide with heavy electrical demand periods?

If yes,
- o Reschedule equipment use so it does not operate when higher utility demand rates are in effect.

NOTES:

YES NO A-9 Are blinds and curtains used to help insulate the building?

If no,
- o Close blinds and curtains to reduce night heat loss in winter, daytime heat gain in summer.
- o Place reminders where appropriate.

NOTES:

YES NO A-10 Are maintenance records available for motors and motor-driven equipment?

If no, o Prepare an up-to-date list of all motors, using name-plate data and indicate routine maintenance performed on each.

NOTES:

YES NO A-11 Are control devices inspected on a regular basis?

If no, o Routinely check and calibrate controls.

NOTES:

YES NO A-12 Is conditioned air or heated water discarded?

If yes, o Check system to be sure there is a minimum of exhaust air or loss of hot water.

NOTES:

YES NO A-13 Are heating and ventilating systems turned off when not required or used?

If no, o Turn off systems where possible when not in use.

NOTES:

YES	NO		
		A-14	Are doors, especially overhead service doors in maintenance areas, left open during operation of the building's heating system?

If yes,

- o Place notices reminding occupants to keep doors closed.
- o Establish routine procedures for minimizing the time service doors are open.
- o Consider retrofit options if management measures do not solve problem, such as air curtains, vinyl strips, automatic door closures, etc.

NOTES:

ENERGY SURVEY CHECKLIST: LIGHTING

YES	NO		
		L-1	Are lighting levels proper for the tasks performed in the area? (A small light meter will be necessary to measure light levels. See appendix for recommended levels.)
		If no,	o Remove some lamps or reduce lamp wattage in over-illuminated areas. o Consider retrofitting to provide task lighting where appropriate rather than illuminating the entire area.
		NOTES:	
YES	NO	L-2	Are switches localized so that when one light or bank of lights are needed they can be turned on separately rather than lighting an entire area?
		If no,	o Consider installing localized light switches. No O & M action practical.
		NOTES:	
YES	NO	L-3	Are incandescent lamps used in offices, workrooms, hallways, shops and service bays?
		If yes,	o Replace bulbs with lower wattage bulbs, where possible. o Discontinue use of multi-level and extended service lamps, except in special cases (recessed fixtures). o Consider retrofit to fluorescent or most efficient light source.
		NOTES:	

YES NO L-4 Have ballasts been disconnected in fixtures where fluorescent lamps have been removed?

If no, o Disconnect ballasts, since they consume energy even though tubes have been removed.

NOTES:

YES NO L-5 Have more efficient lights been installed to replace burned out fluorescent lamps and/or ballasts?

If no, o Replace tubes and ballasts with lower wattage and/or more efficient types.

o Consider not replacing burned out tubes and disconnect ballasts where delamping is possible.

NOTES:

YES NO L-6 Are lamps and fixtures clean?

If no, o Clean lamps and fixtures and establish regular inspection and cleaning schedule. Dust and dirt reduce effectiveness.

NOTES:

YES NO L-7 Is exterior lighting used?

If yes,

- o Make certain all exterior lights are off during daylight hours, within safety considerations.
- o Switch off exterior lights at night when not needed for security.

NOTES:

YES NO L-8 Are lights on in unoccupied areas, such as storage areas?

If yes,

- o Turn lights off when not needed.
- o Post signs reminding occupants to turn lights off when leaving room.
- o Consider retrofitting with automatic device, such as a timer, to turn lights off.

NOTES:

YES NO L-9 Is natural lighting used where possible?

If no,

- o Turn lights off when natural lighting from windows, skylights, open doors, etc. is sufficient.
- o Clean walls and repaint with light reflective, non-glossy colors.
- o Consider relocating work stations so that those needing the most light are located near windows.

NOTES:

YES NO L-10 Have two lamps been removed from four-lamp fixtures where possible?

If no,

- o Remove lamps and disconnect ballasts.

NOTES:

ENERGY SURVEY CHECKLIST: BUILDING ENVELOPE

YES NO B-1 Are windows and doors improperly aligned and operated so as to allow excessive infiltration?

If yes, o Repair windows or doors by realigning or rehanging them, making sure automatic door closing mechanisms work properly and replacing faulty gaskets in overhead garage service doors.

NOTES:

YES NO B-2 Is ceiling/roof insulation adequate and free from water damage?

If no, o Inspect insulation and consider repairing or replacing faulty or inadequate insulation.

NOTES:

YES NO B-3 Is weather stripping and caulking worn, broken or missing around windows, doors, conduits, piping, exterior joints or other areas of infiltration?

If yes, o Replace or repair weather stripping or caulking at points of infiltration.

NOTES:

YES NO B-4 Is there excessive glazing or glass on exterior walls?

If yes,
- o When replacing windows, use thermopanes.
- o Panel over and insulate unnecessary windows.
- o Keep curtain and blinds closed where possible.

NOTES:

YES NO B-5 Is there insulation between heated/cooled and unconditioned spaces or outside areas?

If no,
- o Consider an in-depth cost/benefit analysis of adding insulation. No O & M measures practical.

NOTES:

ENERGY SURVEY CHECKLIST: VENTILATION

YES NO V-1 Is an excessive quantity of outside air used to ventilate the building?

If yes,
- o Reduce outside air use to minimum within code and safety requirements by adjusting outdoor air dampers, except for economizer cooling cycle.

NOTES:

YES NO V-2 Are outdoor air intake dampers open when the building is unoccupied?

If yes,
- o Be sure dampers are closed when building is unoccupied. Check seals to ensure complete closure.
- o If codes and safety requirements permit, close dampers during first and last hours of occupancy for fast warm-up and cool-down.

NOTES:

YES NO V-3 Are ventilation systems used for natural cooling?

If no,
- o Use outside air for cooling rather than mechanical refrigeration. Use economizer cycle, if available.

NOTES:

YES NO V-4 Is the operation of the exhaust system programmed?

If no,
- o Establish schedules so exhaust fans run only when needed.
- o Discontinue use of unnecessary fans, e.g., require toilet exhaust fans to run only when lights are on.

NOTES:

YES NO V-5 Are return, outdoor air and exhaust dampers clean and sequencing properly?

If no,
- o Clean dampers.
- o Adjust damper linkage.
- o Check damper motors for proper operation.
- o Check tightness of damper blade closure and reset linkage or replace dampers as necessary.

NOTES:

YES NO V-6 Does the temperature of air flow to heated space feel too cold during the heating season?

If yes,
- o Reduce air volume to eliminate drafts.
- o Adjust supply temperatures in a zone system.

NOTES:

YES NO V-7 Does air flow to space feel unusually low or is it inconsistent from one space to another?

If yes,
- o Check ductwork for obstruction (hanging insulation, loose turning vanes).
- o Inspect room air inlets and outlets for dirt and obstructions.
- o Clean or replace dirty filters regularly.

NOTES:

YES NO V-8 Do motors vibrate excessively or create excessive noise? Are all drive belts in position and in good condition? Are the fan belt drive and motor properly aligned?

If no,
- o Correct misalignment, repair motors, and/or replace frayed belts.

NOTES:

YES NO V-9 Are outside air supply units turned off during warm weather?

If no,
- o Turn units off where air flow is not required.

NOTES:

ENERGY SURVEY CHECKLIST: HEATING

YES NO H-1 Are multiple boilers or heaters firing simultaneously?

If yes, o Adjust controls so second boiler does not fire until lead boiler can no longer satisfy demand.

NOTES:

YES NO H-2 Does the stack temperature appear excessively high, e.g., greater than 400°F plus room temperature?

If yes,

- o Examine and clean air intake filters.
- o Ensure that the proper amount of air for combustion is available in the furnace room.
- o Make flue gas analysis on regular basis to ensure proper air to fuel ratio.
- o If furnace is overfiring, check spuds and nozzles for proper sizing.

Note: If qualified personnel are not on staff, obtain assistance from service contractor.

NOTES:

YES NO H-3 Is water in heating system heated when there is no need, so that a room or area is simultaneously heated and cooled?

If yes, o Turn heating unit off.

NOTES:

YES NO H-4 Are space temperatures higher or lower than thermostat settings?

If yes,
- o Recalibrate thermostat and controllers.
- o Check control valves and dampers for proper modulation.
- o Check for obstructions in distribution system.
- o Check heat generating device for proper operation.
- o Make sure air intake volume is not excessive.

NOTES:

YES NO H-5 Does the heating system's hot water temperature feel excessively hot during periods of mild weather?

If yes,
- o Reset boiler water temperatures seasonally so that it operates at as low a temperature as possible.

NOTES:

YES NO H-6 Is condensate from the steam system being discharged to the drain?

If yes,
- o Consider retrofit for heat recovery. No O & M measures practical.

NOTES:

YES NO H-7 Are heating pilot lights on during cooling season?

If yes, o Turn pilots off. Post reminder notice in boiler/furnace room.

NOTES:

YES NO H-8 Do steam radiators or other steam equipment fail to heat or operate properly?

If yes, o Check steam traps, thermostatic traps, thermostatic control valves and air vent valves for proper operation. Clean, repair or replace as necessary and establish routine maintenance program.

NOTES:

YES NO H-9 Is insulation on steam, condensate and heating water piping in disrepair or missing?

If yes, o Repair or replace faulty insulation.

NOTES:

YES NO H-10 Is the operation of the oil burner accompanied by excessive smoke and soot?

If yes,

- o Check burner nozzles for wear, dirt and incorrect spray angles. Clean and adjust if necessary.
- o Check oil flow and oil pressure.
- o Perform flue gas analysis to set proper fuel to air ratio.

NOTES:

YES NO H-11 Are soot and odors detected in areas where they are not expected?

If yes,

- o Check heat exchanger and replace if burned out.
- o Check adequacy of stack draft and clean if necessary.
- o Perform flue gas analysis.

NOTES:

YES NO H-12 Is there evidence of faulty or inefficient boilers or furnaces?

If yes,

- o Remove deposits and sediments on water side surfaces.
- o Remove soot from tubes.
- o If fire does not cut off immediately when unit shuts down, check for faulty solenoid valve.
- o Inspect boiler insulation, refractory, brick work and boiler casings for hot spots and air leaks.

NOTES:

YES NO H-13 Is air humidified?

If yes,

- o Discontinue or reduce humidification where possible.

NOTES:

YES NO H-14 Does the burner short-cycle?

If yes,

- o Check hot water temperature limit switch and reset if too low.
- o Check thermostat for proper operation. Replace if necessary.

NOTES:

YES NO H-15 Is the combustion air to boiler/furnace preheated?

If no,

- o Consider heat recovery device as a retrofit option to preheat combustion air. No O & M action practical.

NOTES:

YES NO H-16 Do hot water radiation units fail to operate?

If yes,

- o Check radiators for air-locks. Bleed if necessary.
- o Check for air leaks in pneumatic air lines and bleed if frozen.
- o Repair faulty valves and thermostats.
- o Check hot water pump or booster pump for proper operation. Repair or replace if necessary.

NOTES:

YES NO H-17 Are radiators, convectors, baseboards and finned-tube heaters providing sufficient heat?

If no,

- o Check for excess dirt or air blockage and establish cleaning schedule.
- o Check supply temperature (water or steam).
- o Check traps, vents, circulating pumps and piping gradient.
- o Refer to checks recommended for H-16.

NOTES:

ENERGY SURVEY CHECKLIST: COOLING

YES	NO		
		C-1	Is space temperature higher or lower than thermostat setting?

If yes,

- o Check and calibrate space thermostat.
- o Check and calibrate controllers.
- o Check control valves and dampers for proper modulation.
- o Limit excessive outdoor air intake (when not operating economizer cycle).
- o Clean pneumatic lines (for pneumatic system).

NOTES:

YES	NO		
		C-2	Is the chiller operating during cold weather to provide air conditioning?

If yes,

- o Use outside air cooling.
- o Consider retrofit option of replacing thermostat to provide fixed heating/cooling differential and system cycling.

NOTES:

YES NO C-3 Are reheat coils used to maintain zone temperature?

If yes, o Consider retrofit to variable air volume system. No O & M measure practical.

NOTES:

YES NO C-4 Do multiple air-conditioning compressors start at same time?

If yes, o Set controls so one compressor starts and is fully loaded before second machine starts.

NOTES:

YES NO C-5 Does building use a dual duct or multizone system?

If yes, o Reset hot and cold decks to median temperature to minimize mixing.

o Check dampers for proper sequencing.

o Possibly reduce system air capacity in winter.

NOTES:

YES NO C-6 Does insulation on cooling line pipes and ducts appear adequate?

If no, o Repair or replace damaged insulation.

NOTES:

YES NO C-7 Does air conditioning load trip circuit breaker on extremely warm days?

If yes, o Tighten loose wire lugs.

o Check and replace defective circuit breakers.

o Check cooling tower or condenser for proper operation; clean condenser (air-cooled system) or remove scale build-up (water-cooled systems).

NOTES:

YES NO C-8 Is air of inadequate volume or temperature being discharged through grills so that cooling system is not able to supply room or area needs?

If yes, o Check air supply ducts and cooling coils for dirt and obstructions. Check and/or remove obstruction as necessary.

o Check dampers for proper operation and repair as necessary.

NOTES:

YES NO C-9 Are refrigeration condensers or coils dirty, clogged and/or not functioning effeciently?

If yes,
- o Clean and put on regular maintenance all condensers and coils.
- o Straighten fin coil surfaces.
- o Check for clogged strainer.

NOTES:

YES NO C-10 Are chilled water piping, valves and fittings leaking?

If yes,
- o Repair joint or piping leaks and repair or replace valves.

NOTES:

YES NO C-11 Is the chiller operation optimized? (Listen for short-cycling.)

If no,
- o Raise chilled water supply temperature (especially important if system designed for 75°F and setting has been raised to 78°F).
- o Check dead band setting.
- o Remove scale deposits from condensers.

NOTES:

YES NO C-12 Does refrigeration compressor short-cycle?

If yes,

- o Increase dead band on controls.
- o Check for low charge or leaks in refrigerant.
- o Repair electrical control circuit.
- o Reset high/low pressure differential.
- o Check liquid line solenoid valve for leaks.
- o Check evaporation coil for ice or dirt.
- o Check strainer for clogs.
- o Clean condenser coil.
- o Check for dirt, obstructions in cooling tower and for plugged nozzles.
- o Remove scale deposits from shell/tubes on water condenser.
- o Repair suction valves in compressor.

NOTES:

YES NO C-13 Does the refrigeration compressor run continually? (Direct expansion sytems.)

If yes,

- o Check for excessive outdoor air to evaporation coil.
- o Check for fused starter circuits in controls.
- o Check refrigerant charge (may be too high or low.)
- o Check for leaking compressor valves.
- o Check for stuck liquid line solenoid valve.

NOTES:

YES	NO	C-14 Is the chilled water temperature maintained too cold?
		If yes, o Reset to highest chilled water temperature that will maintain comfort level.
		NOTES:

ENERGY SURVEY CHECKLIST: WATER

YES	NO	W-1	Are storage tanks, piping and water heaters properly insulated?
		If no,	o Replace damaged or missing insulation.
		NOTES:	
YES	NO	W-2	Are drips or leaks evident in the hot water systems?
		If yes,	o Repair all leaks, including faucets and pumps.
		NOTES:	
YES	NO	W-3	Does the electric water heater have a time restrictor on the heating cycle?
		If no,	o use "vacation cycle" on water heater when not needed during excessive periods. (Note: Turning heater off completely could cause leaks.) o Where demand rates apply, heat only during off-peak periods.
		NOTES:	

YES NO W-4 Have devices to conserve heated water been utilized where practical?

If no, o Insert flow restrictors (available from many local utilities) into shower and lavatory fixtures.

NOTES:

YES NO W-5 Is the domestic hot water temperature set too high?

If yes, o Reduce temperature to 105°F, unless used for special purposes or code requires otherwise.

NOTES:

ENERGY SURVEY CHECKLIST: SUMMARY

ADMINISTRATION

A-1 Thermostats on heating/cooling units are vulnerable to occupant adjustment.

A-2 Thermostat settings have not been adjusted for change in seasons.

A-3 Unoccupied or little-used areas are heated or cooled unnecessarily.

A-4 Off-hour activities are scheduled.

A-5 Building temperatures are not adjusted for unoccupied periods.

A-6 Heating/cooling equipment is operating in lobbies, corridors, vestibules and/or other public areas.

A-7 Heating/cooling equipment is started before occupants arrive and/or is operating during the last hour of occupancy.

A-8 Use of equipment that is not required at a specific time coincides with heavy electrical demand periods.

A-9 Blinds and curtains are not used to help insulate the building.

A-10 No records of maintenance for motors and motor-driven equipment are available.

A-11 Control devices are not inspected on a regular basis.

A-12 Conditioned air or heated water is discarded.

A-13 Heating and ventilating systems are not turned off when not required or used.

A-14 Doors, especially overhead service doors in maintenance areas, are left open during operation of the building's heating system.

LIGHTING

L-1 Lighting levels are not proper for the tasks performed in the area.

L-2 Switches are not localized so that when one light or bank of lights are needed they can be turned on separately.

L-3 Incandescent lamps are used in offices, workrooms, hallways and gymnasiums.

L-4 In fixtures where fluorescent lamps have been removed, the ballasts have not been disconnected.

L-5 When burned out fluorescent lamps and/or ballasts have been replaced, more efficient lights have not been installed.

L-6 Lamps and fixtures are not clean.

L-7 Exterior lighting is used.

L-8 Lights are on in unoccupied areas.

L-9 Natural lighting is not optimized.

L-10 Two lamps have not been removed from four-lamp fixtures where possible.

BUILDING ENVELOPE

B-1 Improper alignment and operation of windows and doors allows excessive infiltration.

B-2 Ceiling/roof insulation is inadequate or has been water damaged.

B-3 Weather stripping and caulking around windows, doors, conduits, piping, exterior joints, or other areas of infiltration are worn, broken or missing.

B-4 Excessive expanses of glass exist on exterior walls.

B-5 There is no insulation between conditioned and unconditioned spaces.

VENTILATION

V-1 An excessive quantity of outdoor air is used to ventilate the building.

V-2 Outdoor air intake dampers open when building is unoccupied.

V-3 Ventilation systems are not used for natural cooling capability.

V-4 Exhaust system operation is not programmed.

V-5 Return, outdoor air and exhaust dampers are not sequencing properly.

V-6 During heating season, temperature of air flow to space feels too cold.

V-7 Air flow to space feels unusually low or is inconsistent from one space to another.

V-8 Motors vibrate excessively and/or create excessive noise. Drive bolts are not in position or good condition. Fan belt drive and motor are not properly aligned.

V-9 Outside air supply units not turned off during warm weather.

HEATING

H-1 Multiple boilers or heaters fire simultaneously.

H-2 Stack temperature appears excessively high (greater than 400°F plus room temperature).

H-3 Water in heating system is heated when there is no need.

H-4 Space temperatures are higher or lower then thermostat settings.

H-5 Heating system's hot water temperature feels excessively hot during periods of mild weather.

H-6 Condensate from street steam is being discharged to sewer drain.

H-7 Heating pilot lights are on during cooling season.

H-8 Steam radiators or other steam equipment fail to heat or operate erratically.

H-9 Steam, condensate and heating water piping insulation is in disrepair or missing.

H-10 Operation of oil burner is accompanied by excessive smoke and soot.

H-11 Soot and odors are detected in areas where they are not expected.

H-12 Evidence indicates faulty or inefficient boilers or furnaces.

H-13 Air is humidified.

H-14 Burner short-cycles.

H-15 Combustion air to boiler/furnace is not preheated.

H-16 Hot water radiation units fail to operate.

H-17 Radiators, convectors, baseboards and finned-tube heaters are not providing sufficient heat.

COOLING

C-1 Space temperature is higher or lower than thermostat setting.

C-2 Chiller is operating during cold weather to provide air conditioning.

C-3 Reheat coils are used to maintain zone temperatures.

C-4 Multiple air conditioning compressors start at the same time.

C-5 Building uses a dual duct or multizone system.

C-6 Insulation on cooling line pipes and ducts appears inadequate.

C-7 Air conditioning load trips circuit breaker on extremely warm days.

C-8 Air of inadequate volume or temperature is being discharged through grills.

C-9 Refrigeration condensers or coils are dirty, clogged and/or not functioning efficiently.

C-10 Chilled water piping, valves and fittings are leaking.

C-11 Chiller operation is not optimized. (Listen for short-cycling.)

C-12 Refrigeration compressor short-cycles.

C-13 Refrigeration compressor runs continually. (Direct expansion systems.)

C-14 Chilled water temperature is maintained too cold.

WATER

W-1 Storage tanks, piping and water heaters are not properly insulated.

W-2 Drips or leaks are evident in hot water system.

W-3 Electric water heater has no time restrictions on heating cycle.

W-4 Devices to conserve heated water have not been used where practical.

W-5 Domestic hot water temperature set too high.

FIELD GUIDE

APPENDICES

APPENDIX A:

ENERGY TERMS AND CONVERSION FACTORS

TERMS FOR UNITS OF ENERGY

BTU	=	British Thermal Unit, the basic measure of energy
MBTU	=	1×10^6 BTU = 1,000,000 BTU's
KWH	=	Kilowatt Hour = 1,000 Watt Hours
CF	=	Cubic Feet of Gas
CCF	=	Hundreds of Cubic Feet
THERM	=	CCF = 100 Cubic Feet of Gas
MCF	=	Thousands of Cubic Feet
HP	=	Horsepower

NOMINAL ENERGY EQUIVALENTS

Energy Source	Amount	BTUs
Electricity	1 KWH	3,413
Natural Gas	1 Therm	100,000
Steam	1 Pound	1,000
Oil (#2)	1 Gallon	140,000
Oil (#6)	1 Gallon	160,000
Horsepower	1	42.41/minute
Gasoline	1 Gallon	125,000
Propane	1 Gallon	91,500
Butane	1 Gallon	102,600
LPG Gas	1 Gallon	95,475

APPENDIX B:

ENERGY PROFILE WORKSHEETS

ENERGY PROFILE WORKSHEET 1-A

Electricity

Building_____Year_____

Month	$ Amount	KWH	×3413=BTUs	÷1,000,000=Million BTUs
January				
February				
March				
April				
May				
June				
July				
August				
September				
October				
November				
December				
Annual Totals				

ENERGY PROFILE WORKSHEET 1-B

Gas

Building_____Year_____

Month	$ Amount	Therms	×100,000=BTUs	÷1,000,000=MBTUs
January				
February				
March				
April				
May				
June				
July				
August				
September				
October				
November				
December				
Annual Totals				

ENERGY PROFILE WORKSHEET 1-C

Oil

Building _____ Year _____

Month	$ Amount	Gallons	×140,000 (#2) 160,000 (#6) =BTUs	÷1,000,000=MBTUs
January				
February				
March				
April				
May				
June				
July				
August				
September				
October				
November				
December				
Annual Totals				

ENERGY PROFILE WORKSHEET 1-D

Steam

Building _____ Year _____

Month	$ Amount	Pounds	×1,000=BTUs	÷1,000,000=MBTUs
January				
February				
March				
April				
May				
June				
July				
August				
September				
October				
November				
December				
Annual Totals				

ENERGY PROFILE WORKSHEET 2-A

Annual Energy Use

Building_____ Year_____

Month	MBTUs Steam	MBTUs Gas	MBTUs Oil	MBTUs Elec.	Total MBTUs
January					
February					
March					
April					
May					
June					
July					
August					
September					
October					
November					
December					
Annual Totals					

ENERGY PROFILE WORKSHEET 2-B

Energy Use Summary (in MBTUs)

Building_____

Month	19____	19____	19____	19____
January				
February				
March				
April				
May				
June				
July				
August				
September				
October				
November				
December				
Annual Totals				

ENERGY PROFILE WORKSHEET 2-C

EUI (Energy Utilization Index) Summary (in MBTUs/sq ft)

Building_____ Area in Square Feet_____

Month	19____	19____	19____	19____
January				
February				
March				
April				
May				
June				
July				
August				
September				
October				
November				
December				
Annual Totals				

ENERGY PROFILE WORKSHEET 3-A

Proportion of Energy Use By Source

Building _____

Year _____ Total Annual Energy used _____ MBTU

ELECTRICITY	NATURAL GAS
Proportion of Total _____%	Proportion of Total _____%
ENERGY USES:	ENERGY USES:
1.	1.
2.	2.
3.	3.
4.	4.
5.	5.
OIL	**PURCHASED STEAM**
Proportion of Total _____%	Proportion of Total _____%
ENERGY USES:	ENERGY USES:
1.	1.
2.	2.
3.	3.
4.	4.
5.	5.

APPENDIX C:

CALCULATIONS FOR ESTIMATING ENERGY USE BY FUNCTION

CALCULATIONS FOR ESTIMATING

ENERGY USE BY FUNCTION

The worksheets for Step 2 provide the basic data for tracking a building's overall energy use. They are sufficient for a conservation program that focuses on the no-cost/low-cost O & M actions, as described in Steps 3 and 4. However, more detailed analysis of a building's energy use will be required for conservation programs that include the capital-intensive energy conservation measures discussed in Step 5. This additional analysis involves technical calculations of the energy use for each function--that is, the amount of energy consumed for lighting, heating, power machinery and other purposes. The end product will be a more detailed energy pie chart, as shown in Figure 3.

In this appendix instructions and basic formulas are provided for estimating the energy used by these major functions:

lighting
HVAC equipment
miscellaneous equipment
comfort heating, (heat loss, infiltration and make-up air).

Because these calculations can be very complex, it is strongly recommended that technical assistance be obtained, especially if trained engineers are not on the agency's staff. Local utilities and state energy offices may be able to provide the necessary expertise, as can energy consultants or engineering firms.

Lighting: Energy Profile Worksheet 4-A

Estimating the electrical energy consumed by the lighting system requires an inventory of all installed interior and exterior lighting fixtures, including their wattage and the estimated annual hours of operation. Information on lighting fixtures and wattage can be obtained from building plans and design documents. However, this information should also be field verified to account for any changes in original plans. Annual hours of operation can be estimated by the building's operating and maintenance personnel.

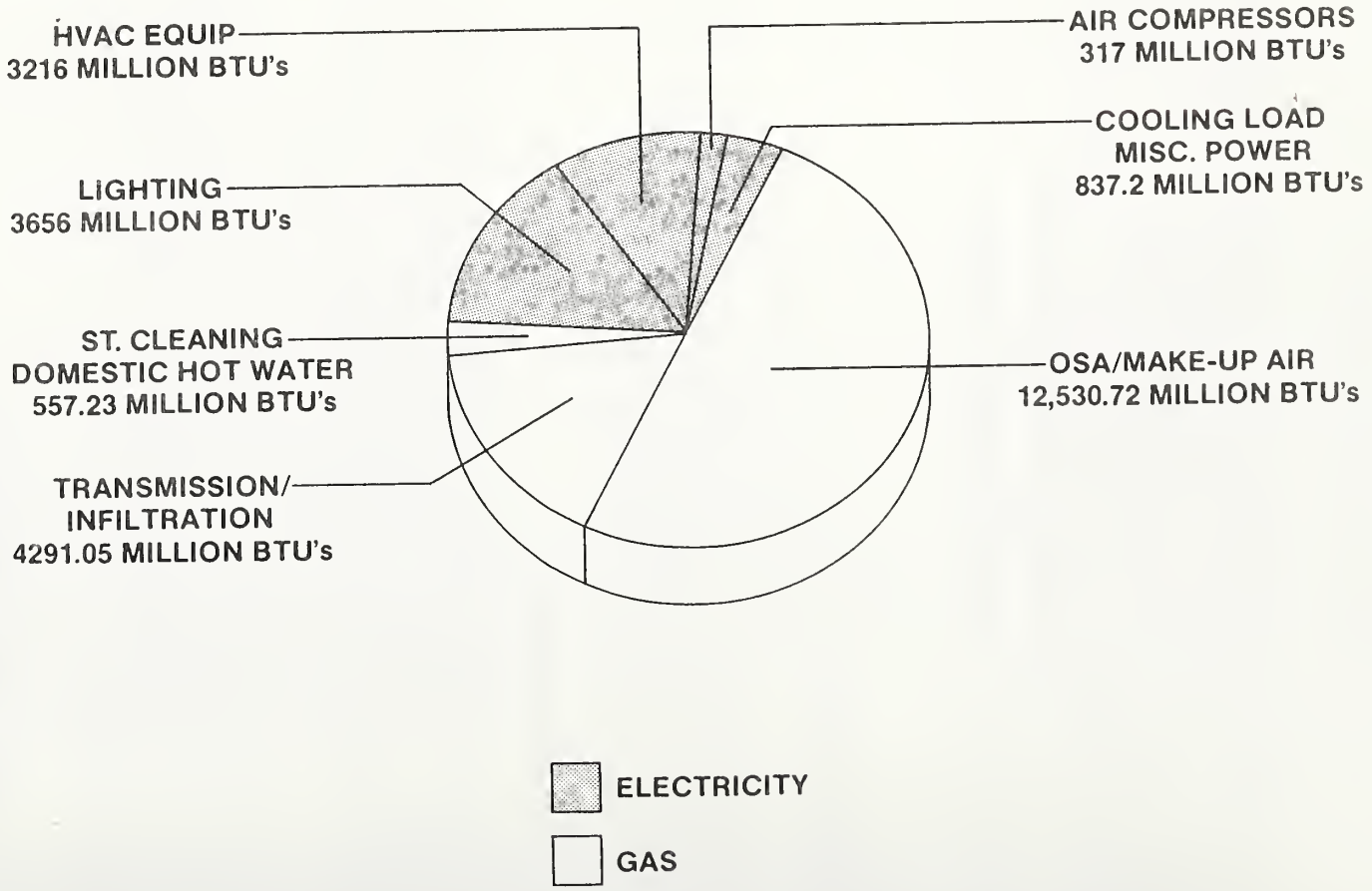
Energy profile worksheet 4-A can be used to record the necessary data for calculating the energy consumption for lighting. For large facilities, a separate worksheet can be completed for each room or work area. The worksheet contains space for entering the type of fixture (fluorescent, incandescent, sodium), the electrical load per fixture (in watts), the number of fixtures, the annual hours of operation and the total annual electrical use in kilowatt hours.

HVAC Equipment: Energy Profile Worksheet 4-B

Estimating the energy used by air supply and exhaust fans, pumps and other mechanical equipment associated with the building's heating, ventilating and air conditioning (HVAC) system is analogous to the calculations for the lighting consumption, though somewhat

FIGURE 3:

Energy Use By Function



ENERGY PROFILE WORKSHEET 4-A

Electrical Energy Consumption: Lighting

Building _____ Date Completed _____

A	B	C	D	E	F	G
Location	Fixture Description	Number of Fixtures	Electrical Load Per Fixture (In Watts)	Total Electrical Load (In Watts)	Operating Hours/Year	Annual Electrical Use (In KWH)
					Total KWH	

Column E = C × D

Column G = $\frac{E \times F}{1{,}000}$

ENERGY PROFILE WORKSHEET 4-B

Electrical Energy Consumption: HVAC Equipment

Building _____ Date Completed _____

A	B	C	D	E	F	G	H	I	J
Location	Equipment Description	Rated Load In HP	Operating Amps	Maximum Rated Amps	Load Factor	Estimated Load (in KW)	Number of Devices	Operating Hours Per Year	Annual Electrical Use (in KWH)
								Total KWH	

Column F = Column D ÷ Column E
Column G = Column C × Column F
Column I = Columns G × H × I

more complex. As with the lighting calculations, it is necessary to survey the HVAC equipment, determine the average load for each piece of equipment and estimate the annual hours of operation.

Energy profile worksheet 4-B can be used to make these calculations. Information on the type and number of HVAC equipment can be collected from building design documents and plans and should be field verified to account for any changes. The **rated load** of each piece of equipment, usually expressed in horsepower units, can be obtained from the nameplate, design documents or maintenance literature.

Because the average load on a piece of equipment is normally a fraction of the rated load, it is necessary to adjust the rated load by a **load factor**. Under normal operating conditions, the load factor can be determined by measuring the actual operating amps and dividing that number by the maximum rated amps, as shown on the nameplate. Thus,

$$\text{LOAD FACTOR} = \frac{\text{OPERATING AMPS}}{\text{MAXIMUM RATED AMPS.}}$$

Then, multiplying the rated load by the load factor produces the estimated load in kilowatt hours. Finally, annual hours of operation can be estimated by the building's operating and maintenance personnel.

Miscellaneous Equipment: Energy Profile Worksheet 4-C

In addition to the HVAC equipment, miscellaneous electrical equipment, like air compressors, hoists, hydraulic jacks and other major pieces of machinery should be considered. As with the HVAC equipment, the rated load of each machine can be obtained from the nameplate, design documents or maintenance literature. Similarly, the load factor can be determined by the formula:

$$\text{LOAD FACTOR} = \frac{\text{OPERATING AMPS}}{\text{MAXIMUM RATED AMPS.}}$$

Determining the operating hours of each device may be somewhat difficult, unless the actual operating time has been logged. However, an estimate of operating hours can be made by talking with personnel familiar with the machinery or by logging the use of the device for a few days at random. Since energy profile worksheet 4-C is identical to worksheet 4-B, refer to the preceding discussion of worksheet 4-B for more instructions.

ENERGY PROFILE WORKSHEET 4-C

Electrical Energy Consumption: Miscellaneous Equipment

Building _____ Date Completed _____

A	B	C	D	E	F	G	H	I	J
Location	Equipment Description	Rated Load In HP	Operating Amps	Maximum Rated Amps	Load Factor	Estimated Load (in KW)	Number of Devices	Operating Hours Per Year	Annual Electrical Use (in KWH)
								Total KWH	

Column F = Column D ÷ Column E
Column G = Column C × Column F
Column I = Columns G × H × I

Comfort Heating: Energy Profile Worksheet 4-D

Estimating the energy used by the building's comfort heating system involves several complex calculations. In order to arrive at an accurate estimate of the energy used to heat a building, calculations must be made to account for heat loss due to transmission and infiltration as well as the energy required to raise outside or make-up air to room temperature. Figure 4 shows a conceptual overview of these three basic components of a building's heating load.

The following sections discuss the methods for estimating the energy required to compensate for heat loss due to transmission, infiltration and outside air. Examples are given for each calculation.

Transmission (or conduction) is the energy required to compensate for heat conducted through the building envelope, e.g., walls, roofs, doors, windows and floors. The basic formula for calculating heat loss by transmission or conduction is:

$Q = U \times A \times TD$ **where**

Q	=	heat transfer rate in BTU/hour
U	=	heat transfer coefficient (see tables in Appendix E)
A	=	area
TD	=	temperature difference between inside and outside temperature in degrees Fahrenheit.

The key element in the transmission formula is the "U" factor, or the **heat transfer coefficient,** which varies according to the materials that make up the walls, doors and other parts of the building envelope.

The heat transfer coefficient is also referred to as **thermal conductance.** As this term implies, it is an expression of how slow or fast heat is transferred from an area of higher temperature to an area of lower temperature in an attempt to reach equilibrium.

Since the inverse to "U" or thermal conductance is "R" or resistance, as in electricity, "U" is most easily determined by summing the individual resistance values for each component in a wall or roof and then inverting the total "R" values. The exact composition of each portion of the envelope can be obtained from the building's architectural plans and should be site verified. Some "R" values may be found in building specifications or obtained from the manufacturer for recent installations like skylights and fire domes. "R" and "U" values for common building materials are listed in Appendix E. Sample calculations are shown in Figure 5 for a maintenance building of recent construction.

Calculating the heat transmission of a building's floor is slightly more involved than summing the "R" value of the materials making up a wall or roof, especially for conventional slab on grade construction. According to ASHRAE (the American Society of Heating, Refrigeration and Air Conditioning Engineers), the heat loss of slabs on grade is proportional to the lineal feet of exposed edge, rather than the total square footage. The formula expressing this relationship is:

FIGURE 4:

Components of Energy Consumption for Comfort Heating

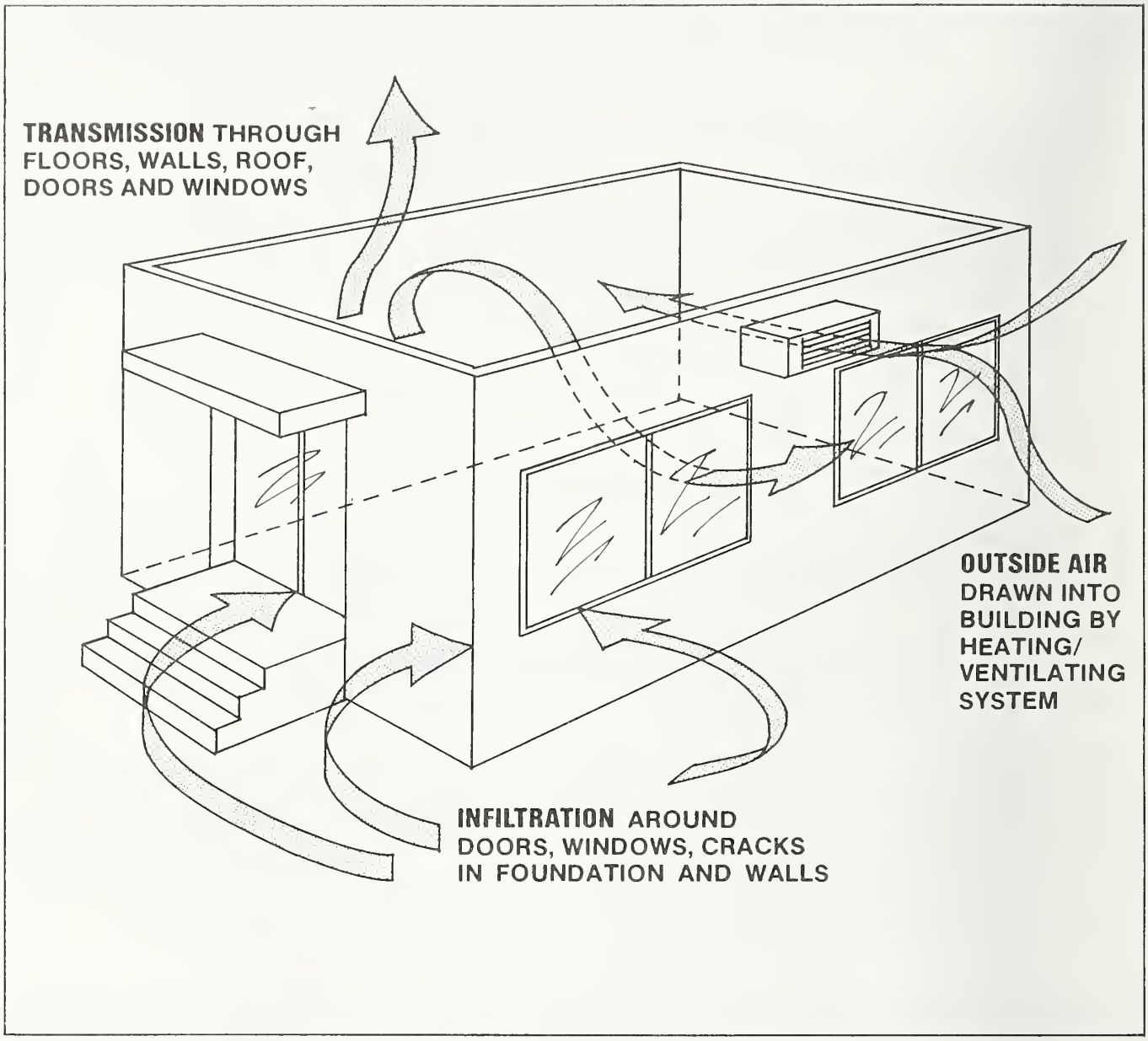
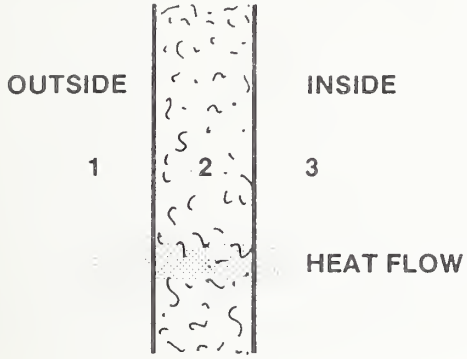


FIGURE 5:

Calculating "U" From "R" Values

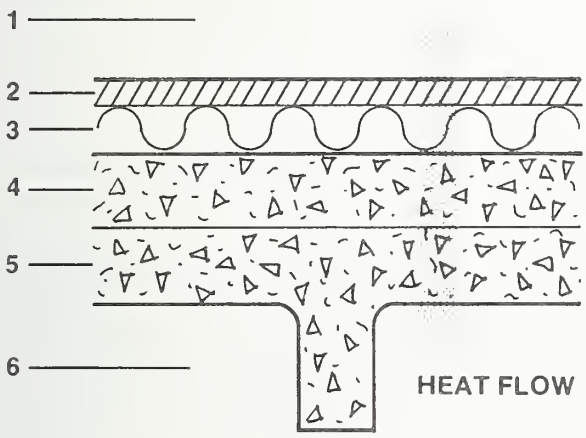
WALLS



No.	DESCRIPTION	R
1	Surface Air Film (outside 15 MPH Wind)	0.17
2	8" Thick Conc. (.08/in x 8")	0.64
3	Surface Air Film (Inside Still Air)	0.68
	R_T =	1.49

$U = 1/R_T = 1/1.49 = 0.67$

ROOF



No.	DESCRIPTION	R
1	Surface Air Film (outside 15 mph wind)	0.17
2	Built up roofing	0.33
3	2" rigid insultaion Conductance < 0.24 1/.24 = (From Project Specifications)	4.17
4	3" Conc. Topping (3 x .08)	.24
5	3" Conc. "T" (3 x .08)	.24
6	Surface Air Film (Inside Still Air)	0.68
		5.83

$U = 1/R_T = 1/5.83 = 0.17$

$Q = F_2 \times P \times TD$ **where**

Q	=	heat transfer rate in BTU/hour
F_2	=	heat transfer coefficient (see table in Appendix E)
P	=	perimeter or exposed edge of floor in linear feet
TD	=	temperature difference between inside and outside temperature in degrees Fahrenheit.

Infiltration is the energy required to compensate for heat loss due to air leakage around doors, windows and exterior walls. With the modern practice of pressurized structures, where more air is supplied than exhausted, the importance of infiltration as a factor of heat loss is substantially reduced. For most modern bus bases, the only significant heat loss due to infiltration is around overhead service doors in maintenance bays.

The formula for calculating infiltration loss is:

$Q = .018 \times CFH \times TD$ **where**

Q	=	heat transfer rate in BTU/hour
.018	=	constant of specific heat of air
CFH	=	total cubic feet per hour transferred
TD	=	temperature difference between inside and outside temperature in degrees Fahrenheit.

CFH--cubic **feet of air per hour transferred**--is a difficult quantity to determine. ASHRAE has published estimates for some types of doors and windows, but determining the CFH for roll-up service doors involves making estimates based on a commonsense approach to the problem. For example, it can be assumed that a 1/16" crack occurs around the entire perimeter of each door, and that air enters through that crack at an average velocity of 150 feet per minute. Using these assumptions, the CFH for a typical service door can be estimated as follows:

Total perimeter of 14' x 14' door = 56'

Area of 1/16' crack = $56' \times \frac{1/16''}{12} = .29\ ft^2$

Flow in cubic feet per minute = $43.8\ ft^3/min$

$F = A \times v$ **where**

F	=	flow in ft^3/min
A	=	area in ft^2
V	=	velocity in ft/min

thus, $F = .29\ ft^2 \times 150\ ft/min = 43.8\ ft^3/min$

Converting $43.8\ ft^3/min$ to cubic feet/hour = $2{,}625\ ft^3/hr$.

Thus, CFH = $2{,}625\ ft^3/hr$ for each 14' x 14' door.

This same method can also be used to calculate the heat lost during the time service doors are open. Many agencies recognize that the practice of leaving service doors open during periods when there is frequent movement of buses in and out of maintenance areas is a major source of heat loss. The formula Q = .018 x CFH x TD will provide a reasonable estimate of this loss. As above, an estimate of CFH of air transferred through the open door can be made by the formula F = A x U. However, in this case, the value of **A** will be the total area of the door opening. A simple application of this formula to the open service door problem is provided in Appendix G.

OSA (OUTSIDE AIR)/Make-Up Air is the heating consumption required to raise the building's make-up air (which is brought in as fresh air or to compensate for exhaust air) from the outside temperature to room temperature. OSA or make-up air is typically the largest energy consumer in a heating system, especially for transit facilities where health and safety considerations require substantial turnover of building air in shops, paint spray booths and similar areas.

The formula for calculating OSA consumption is similar to the formula for infiltration:

Q = 1.08 x CFM x TD **where** Q = heat transfer rate in BTU/hour

1.08 = constant of specific heat of air

CFM = cubic feet per minute of air

TD = temperature difference between inside and outside temperature in degrees Fahrenheit.

In this formula, the volume of air circulated in CFM (cubic feet per minute) can be determined from the HVAC equipment schedule for exhaust and supply air. However, it is often necessary to measure the actual air volume.

The **temperature difference** (TD or ΔT) is the difference between the outside air temperature and the temperature to which the building is heated inside. Comfort heating components are conventionally sized by determining the maximum temperature difference (TD or ΔT) a building will be subjected to during an entire year. ASHRAE publishes winter outside design temperatures for specific locations. Once the inside design temperature is established, the TD can be determined. For example, the winter design temperature for Seattle is 15°F. Thus, if the inside temperature of a building in Seattle is to be maintained at 65°F, the TD is 50°F.

However, in order to estimate the energy required to offset the heat loss over an entire year, it is necessary to know not only the TD, but also the hours per year that the building is subjected to a specific TD. Further, the TD itself varies over time. Though the maximum TD in the example above was 50°F, the building was also subjected to a TD of 49°F for a specific number of hours, 48°F for another period of time and so on. For example, with an interior temperature of 65°F and an exterior temperature of 60°F, the TD was only 5°F.

The Air Force manual **Engineering Weather Data** (see the resource section in the **Office Guide**) provides the information required to calculate the various TD's and hours of occurrence for many cities throughout the country. It is commonly referred to as "BIN data," and when it is used to estimate energy, it is called the **BIN method.** Sample BIN data for Seattle are shown in Figure 6.

To estimate the annual energy consumption using the BIN method, the following data are necessary:

- The average inside building temperature, as estimated by the building's operating and maintenance personnel. Though this number will be a somewhat rough estimate, it should be as accurate as possible.

- The hours of building operations when the heating system is on, which also can be estimated by operating and maintenance personnel.

- The average outside temperature and hours of observed occurrence when the outside temperature is less than the indoor temperature from the BIN tables.

Using the BIN method, sample calculations for a bus maintenance garage in Seattle are shown below. Since this facility is in constant operation (8,760 hours per year) the calculation is based on the annual total from the BIN data on Figure 6.

FIGURE 6:

SEATTLE NSA WASHINGTON

LAT 47 41N LONG 122 15W ELEV 47FT

MEAN FREQUENCY OF OCCURRENCE OF DRY BULB TEMPERATURE (DEGREES F) WITH MEAN CDINCIDENT WET BULB TEMPERATURE (DEGREES F) FDR EACH DRY BULB TEMPERATURE RANGE

Temperature Range	MAY Obsn Hour Cp 01 to 08	MAY 09 to 16	MAY 17 to 24	MAY Total Obsn	MAY MCW8	JUNE 01 to 08	JUNE 09 to 16	JUNE 17 to 24	JUNE Total Obsn	JUNE MCW8	JULY 01 to 08	JULY 09 to 16	JULY 17 to 24	JULY Total Obsn	JULY MCW8
95/99		0		0	65		0		0	67		0	0	0	79
90/94		0		0	67		1	0	1	69		2	1	3	72
85/89		1	0	1	65		2	2	4	68		9	5	14	69
80/84		5	2	7	64		7	4	11	66		20	13	33	67
75/79		8	4	12	62	0	16	10	26	64	0	31	25	56	65
70/74		16	9	25	60	1	33	21	55	61	2	53	41	96	62
65/69	1	32	21	54	57	6	55	41	102	58	15	63	55	133	60
60/64	6	53	39	98	54	30	66	65	161	56	70	52	72	194	57
55/59	33	60	65	164	52	103	47	69	219	54	131	17	33	181	54
50/54	98	50	69	217	49	92	12	26	130	50	29	1	2	32	51
45/49	81	15	34	130	45	9	0	1	10	47	1		0	1	48
40/44	28	1	4	33	41										
35/39	2		0	2	37										

Temperature Range	AUGUST 01 to 08	AUGUST 09 to 16	AUGUST 17 to 24	AUGUST Total Obsn	AUGUST MCW8	SEPTEMBER 01 to 08	SEPTEMBER 09 to 16	SEPTEMBER 17 to 24	SEPTEMBER Total Obsn	SEPTEMBER MCW8	OCTOBER 01 to 08	OCTOBER 09 to 16	OCTOBER 17 to 24	OCTOBER Total Obsn	OCTOBER MCW8
95/99		1	0	1	69										
90/94	0	1	0	1	67		0	0	0	70					
85/89		5	2	7	68		1	0	1	67					
80/84		17	9	26	60		5	2	7	65		0		0	67
75/79		30	19	49	64		16	5	21	64		1	0	1	64
70/74	1	54	38	93	62	0	31	15	46	62		5	1	6	60
65/69	10	66	62	138	60	2	56	37	95	59		19	4	23	58
60/64	88	58	81	227	58	39	70	78	187	57	7	49	24	80	56
55/59	120	16	35	171	55	101	48	76	225	54	40	77	73	190	53
50/54	28	0	3	31	51	78	12	25	115	51	90	67	92	249	50
45/49	1			1	48	18	1	2	21	47	80	24	46	150	40
40/44						1			1	43	29	5	8	42	42
35/39											3	0	0	3	36

Temperature Range	NOVEMBER 01 to 08	NOVEMBER 09 to 16	NOVEMBER 17 to 24	NOVEMBER Total Obsn	NOVEMBER MCW8	DECEMBER 01 to 08	DECEMBER 09 to 16	DECEMBER 17 to 24	DECEMBER Total Obsn	DECEMBER MCW8	JANUARY 01 to 08	JANUARY 09 to 16	JANUARY 17 to 24	JANUARY Total Obsn	JANUARY MCW8
95/99															
90/94															
85/89															
80/84															
75/79															
70/74															
65/69		0		0	56										
60/64	0	3	1	4	54		0		0	52		0		0	51
55/59	4	24	8	36	52	0	4	2	6	52		4	1	5	50
50/54	37	74	54	165	49	18	39	24	81	49	9	21	14	44	48
45/49	77	73	80	236	45	64	79	74	217	45	42	64	57	163	45
40/44	66	43	60	169	40	68	68	73	209	40	72	80	76	228	40
35/39	38	15	24	77	36	58	39	53	150	36	72	50	64	186	36
30/34	13	5	4	22	32	27	13	17	57	31	29	16	22	67	31
25/29	2	1	1	4	25	7	3	2	12	27	12	9	9	30	25
20/24		1	1	2	19	2	1	2	5	20	6	3	5	14	20
15/19	2	0	1	3	16	1	2	1	4	15	5	1	1	7	16
10/14	0			0	14	1	1	1	3	11	0			0	13
5/9						0			0	8					

Temperature Range	FEBRUARY 01 to 08	FEBRUARY 09 to 16	FEBRUARY 17 to 24	FEBRUARY Total Obsn	FEBRUARY MCW8	MARCH 01 to 08	MARCH 09 to 16	MARCH 17 to 24	MARCH Total Obsn	MARCH MCW8	APRIL 01 to 08	APRIL 09 to 16	APRIL 17 to 24	APRIL Total Obsn	APRIL MCW8
95/99															
90/94															
85/89															
80/84															
75/79												1	0	1	59
70/74		0		0	56		0		0	55		4	1	5	58
65/69		1	0	1	55		3	1	4	54		12	4	16	55
60/64		3	1	4	52		9	3	12	52	0	21	12	33	52
55/59	1	13	5	19	50	0	23	9	32	49	2	50	32	84	50
50/54	11	40	25	76	48	6	57	36	99	47	24	81	71	176	47
45/49	43	73	68	184	44	49	86	87	222	44	99	56	83	238	44
40/44	77	60	74	211	40	102	53	78	233	40	87	13	32	132	41
35/39	61	27	40	128	36	67	15	28	110	36	26	0	5	31	37
30/34	24	6	9	39	31	22	2	4	28	31	1		0	1	33
25/29	5	1	2	8	25	1	1	1	3	26					
20/24	2	1	0	3	19	1		0	1	20					
15/19	1	0	0	1	16										
10/14															
5/9															

Temperature Range	ANNUAL TOTAL 01 to 08	ANNUAL TOTAL 09 to 16	ANNUAL TOTAL 17 to 24	ANNUAL TOTAL Total Obsn	ANNUAL TOTAL MCW8
95/99		1	0	1	71
90/94	0	4	1	5	70
85/89		18	9	27	68
80/84		54	30	84	66
75/79	0	103	63	166	64
70/74	4	196	126	326	62
65/69	34	307	225	566	59
60/64	240	384	376	1000	57
55/59	535	389	408	1332	53
50/54	520	454	441	1415	49
45/49	564	471	538	1573	45
40/44	530	323	405	1258	40
35/39	327	146	214	687	36
30/34	116	42	56	214	31
25/29	27	15	15	57	25
20/24	11	6	8	25	20
15/19	9	3	3	15	16
10/14	1	1	1	3	12
5/9	0			0	8

A. Temperature Range	B. Average Outdoor Temperature	C. Indoor Temperature	D. Temperature Difference per Hour	E. Total Observed Hours	F. TD - Hours
60/64	62	64°	2	1000	2000
55/59	57		7	1332	9324
50/54	52		12	1415	16,980
45/49	47		17	1573	26,741
40/44	42		22	1258	27,676
35/39	37		27	687	18,549
30/34	32		32	214	6,848
25/29	27		37	57	2,109
20/24	22		42	25	1,050
15/19	17		47	15	705
10/14	12		52	3	75
5/9	7		57	0	0
				Annual Temperature Difference - Hours:	112,057*

Column A = All temperature ranges at or below indoor temperature from BIN data.

Column B = Average of temperature range

Column D = C minus B

Column E = Hours at temperature range during operating hours

Column F = D times E

* These TD-hours are applicable only for a building in Seattle operated 24 hours, seven days a week and heated to an average interior temperature of 64°F.

Energy profile worksheet 4-D can be completed once the calculations described above have been made. Instructions for each section of the worksheet are summarized below:

Identifying Information

1. Enter name of building, room number and name as appropriate.

2. Enter the reference inside temperature (TR) used in the BIN calculations.

Transmission

1. Enter the "U" value (see Appendix E) for each component of the building envelope, e.g., walls, windows, doors.

2. Enter the area in square feet (A) of each component, e.g., the total square feet of windows. The net wall area can be determined by subtracting the area of the windows and doors from the gross wall area.

3. For the floor (slab on grade), enter the heat transfer coefficient "F_2" (see Appendix E) and the perimeter "P" of the exposed edge of the floor in linear feet.

4. Enter the total annual temperature difference minus hours ("TD-HRS") as determined by the BIN method.

5. Multiply U x A x (TD-HRS) and F_2 x P x (TD-HRS) to arrive at the annual MBTUs (BTU x 10^6) of energy required for each component.

Infiltration

1. Enter the cubic feet per hour "CFH" for infiltration through windows, doors and/or walls.

2. Determine the annual MBTUs of energy consumed by multiplying .018 x CFH x TD-HRS.

OSA/Make-Up Air

1. Enter the cubic feet per minute "CFM" of make-up air.

2. Multiply 1.08 x CFM x TD-HRS to determine MBTUs consumed.

Accounting for System Efficiency

The sum of MBTUs for transmission, infiltration and OSA/make-up air provides the estimated annual heating consumption in millions of BTUs. This sum will need to be adjusted by a **system efficiency factor** to take into account inefficiencies in operation of the heating system. A standard efficiency factor for oil or gas-fired systems is .8; for electric resistance systems the efficiency factor would be 1.0. Thus, the adjusted annual heating consumption is equal to the total estimated consumption from worksheet 4-D divided by the efficiency factor.

Estimating Total Energy Consumption

The estimated total energy consumption for the building can be determined from the total of worksheets 4A through 4D. However, before this total is calculated, it is important to check the estimated totals for each energy source against the actual consumption. For example, estimated consumption totals for electricity should be compared with the actual electrical consumption, as reported from utility billings for the corresponding period of time. In some cases, it will be necessary to convert MBTUs to therms or kilowatts in order to make these comparisons.

ENERGY PROFILE WORKSHEET 4-D

Heating Consumption

Building _____ Date Completed _____

ROOM NO.	ROOM NAME	TR	

TRANSMISSION LOSS				TD-HRS	BTU×10⁶
ITEM	U	A	U×A		
ROOF					
GROSS WALL					
GLASS					
DOORS					
NET WALL					
PERIMETER FLOOR					
	F_2	P	$F_2 \times P$		
INFILTRATION					
ITEM	K	CFH	K×CFH		
WINDOWS	.018				
DOORS					
WALLS					
OSA/MAKE-UP AIR					
	K	CFM	K×CFM		
	1.08				
				TOTAL MBTUs	

CORRECTION FOR SYSTEM EFFICIENCY:

$$\frac{\text{TOTAL MBTUs}}{\text{SYSTEM EFFICIENCY*}} = \text{ADJUSTED TOTAL MBTUs}$$

* System Efficiency = 1.0 For Direct Electrical Resistance Heat, 0.8 For Gas or Oil Fired Systems.

If discrepancies exist between estimated and actual consumption, the assumptions underlying the estimated calculations and the calculations themselves must be reviewed. This review is especially necessary for heating calculations, where a key factor to check is the estimated inside temperature for the TD-HRS calculation. It may be that this figure has been over or underestimated, thus requiring recalculation of the TD-HRS.

Once it has been determined that the consumption estimates are accurate, all energy consumption estimates from worksheets 4-A through 4-C must be converted to MBTUs in order to prepare a chart showing energy use by function (see Figure 3). This chart will provide a graphic overview of the major energy consuming systems and will identify areas where conservation efforts should be directed. For example, the large energy requirements in Figure 3 for OSA/make-up air show that first attention should be given to conserving energy in the make-up air system through energy conservation measures like installation of heat recovery devices.

Some components of a building's energy system have not been included in the above calculations and will have to be estimated by subtracting the estimated consumption for each source from the actual energy consumed. For instance, energy requirements for gas-fired steam cleaning equipment and other miscellaneous devices powered by natural gas can be estimated by subtracting the estimated energy consumption for a gas-fired heating system from the annual volume of natural gas consumed. The energy consumption for electrically powered air conditioning systems can be estimated in a similar fashion. This procedure is especially necessary for estimating the energy consumed by air conditioning, which is not likely to play a central role in the energy picture of most transit facilities and which otherwise requires highly technical calculations to determine.

APPENDIX D:

ENERGY CONSERVATION CASE STUDY

AN ENERGY CONSERVATION CASE STUDY

This case study of a transit operating and maintenance facility has been included to provide a working example for collecting energy consumption data. The case study is based on a recent technical analysis of Seatte Metro's East Operating and Maintenance Base. Included are a brief description of the facility, relevant architectural details, sample worksheets and a summary of the building's energy consumption patterns. Note that energy use data from Step 2--the energy profile--as well as Appendix C have been included in this sample analysis.

General Building Characteristics

The east base facility was built in 1977 and consists of a maintenance building and an adjoining operations building, with a combined area of 73,692 square feet. (A separate fuel and wash building is not included in the analysis.) The maintenance building is the larger of the two. It houses the inspection pits, chassis shop, tire shop, steam cleaning bay and paint shop on the ground floor. Support services and parts storage are on the ground floor as well as on a mezzanine level. The building is oriented east and west and has a large number of service doors located on the north and south elevations.

The operations building is east of the maintenance building, which it adjoins. The operations building is a two-story structure and houses the base's operations and dispatch centers along with classrooms, recreation areas, locker rooms and support services. The construction of the two buildings is similar. The floors are a concrete slab on grade, with recesses and drainage as required for specific activities within the building. The walls are precast concrete. The roofs consist of a concrete roof deck with rigid insulation and a built-up roof.

Mechanical Systems Characteristics

The heating source for the maintenance and operations buildings is two low pressure steam boilers with combination gas and oil burners that use natural gas as the primary fuel.

Supply air is provided to the maintenance building shop areas and toilet rooms with penthouse and rooftop heating and ventilating units. The office and lunchroom areas are supplied with heating, ventilation and cooling from a cabinet fan. Supplemental heat for the lunch room is provided by hot water finned radiation. The heating and ventilating units and air conditioning unit have steam heating coils. The chilled water for the air conditioning is piped from the water chiller located in the operations building.

Exhaust ventilation for the maintenance building shop areas, locker rooms and toilet rooms is provided by 21 exhaust fans. Some of these fans are return-exhaust units with duct connections that allow return air to be recirculated to respective make-up air units.

The operations building air conditioning unit is a climate changer with a chilled water cooling coil and a steam heating coil. Chilled water is provided by a reciprocating chiller located in the same penthouse as the air conditioning unit. The cooling tower is also

located in the penthouse. A steam-to-water converter, heated with steam piped from the maintenance building boilers, provides hot water for circulation to fin tube radiation, convectors and reheat coils. Hot water is pumped to two zones of finned radiation and one convector. The air distribution in this building is with by-pass variable air volume boxes provided with reheat coils.

Domestic hot water is heated with electric heaters in the operations building and with a gas heater and separate storage tank in the maintenance building.

Lighting System Characteristics

Lighting within the Metro east base buildings is primarily fluorescent with some accent lighting provided by incandescent fixtures. Exterior lighting is primarily from high pressure sodium lamps.

Occupancy Patterns

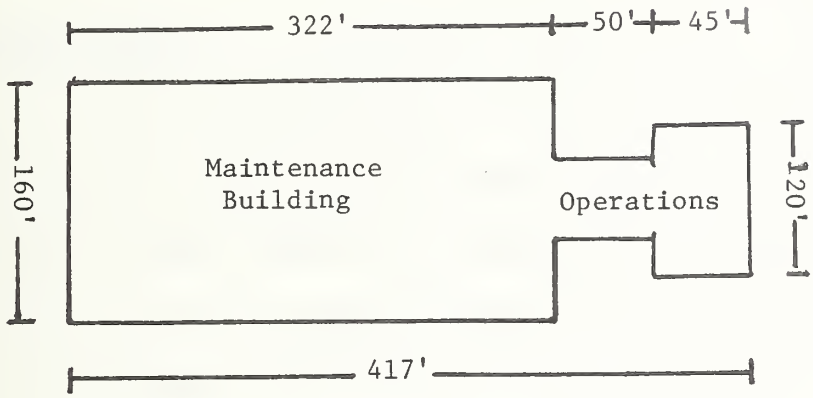
The maintenance building is occupied 24 hours a day, or 8,760 hours/year. Normally ten persons occupy the building for each eight-hour shift. Occupancy of the operations building is less constant, with wide fluctuations in the number of personnel, depending on bus operations. However, the operation building is normally staffed between 4:00 a.m. and 6:30 p.m.

THE FACILITY

Description: East Operating and Maintenance Base

Location: Bellevue, Washington

Layout and Architectural Details:



Maintenance Building

Area:	61,948 ft^2
Floor:	Slab on Grade, 6" thick
Walls:	Concrete tilt up
Roof:	Precast concrete T's with topping slab, rigid insulation and built-up roofing
Roll-Up Doors:	20 @ 14' x 14'
Metal Doors:	22 @ 3' x 7'
Glass:	8' x 8'
Roof Fire Domes:	68

Operations Building

Area:	11,744 ft^2
Floor:	Slab on Grade
Walls:	Precast concrete with insulation and gypsum wallboard
Roof:	Metal deck and concrete (approx. 6" thick) with insulation and built-up roofing
Glass:	4 @ 6' x 20' 3 @ 6' x 15' 7 @ 2' x 15' 2 @ 6' x 10' 2 @ 2' x 5' 1 @ 2' x 5'
Doors:	Negligible

ENERGY PROFILE WORKSHEET 1-A

Electricity

Building EAST BASE Year 1980

Month	$ Amount	KWH	×3413=BTUs	÷1,000,000=Million BTUs
January	4,673.49	209,280	714,273,640	714
February	4,327.72	174,240	594,681,120	595
March	4,672.42	194,880	665,125,440	665
April	6,307.17	195,971	668,849,902	669
May	5,548.48	194,400	663,487,200	663
June	5,101.35	187,200	638,913,600	639
July	4,701.14	205,920	702,804,960	703
August	4,636.74	205,440	701,166,720	701
September	4,485.51	196,800	671,678,400	672
October	4,181.91	182,400	622,531,200	622
November	5,120.51	197,760	674,954,880	675
December	5,184.13	207,360	707,719,680	708
Annual Totals	58,940.57	2,351,651	8,026,184,800	8,026

ENERGY PROFILE WORKSHEET 1-B

Gas

Building EAST BASE Year 1980

Month	$ Amount	Therms	×100,000=BTUs	÷1,000,000=MBTUs
January	9,296.39	24,249.3	24,249,300,000	2,425
February	6,800.41	17,554.9	17,554,900,000	1,755
March	8,763.95	21,817.4	21,817,400,000	2,182
April	5,652.44	12,176.4	12,176,400,000	1,218
May	3,871.33	8,227.4	8,227,400,000	823
June	5,463.86	11,591.0	11,591,000,000	1,159
July	4,601.14	9,633.6	9,633,600,000	963
August	4,627.01	9,494.5	9,494,500,000	950
September	5,228.46	11,044.6	11,044,600,000	1,104
October	6,036.49	13,446.0	13,446,000,000	1,345
November	6,522.06	14,760.8	14,760,800,000	1,476
December	8,888.69	19,772.8	19,772,800,000	1,977
Annual Totals	75,752.23	173,768.7	173,768,700,000	17,377

ENERGY PROFILE WORKSHEET 2-A

Annual Energy Use

Building EAST BASE Year 1980

Month	MBTUs Steam	MBTUs Gas	MBTUs Oil	MBTUs Elec.	Total MBTUs
January		2,425		714	3,139
February		1,755		595	2,350
March		2,182		665	2,847
April		1,218		669	1,887
May		823		663	1,486
June		1,159		639	1,798
July		963		703	1,666
August		950		701	1,651
September		1,104		672	1,776
October		1,345		622	1,967
November		1,476		675	2,151
December		1,977		708	2,685
Annual Totals		17,377		8,026	25,403

ENERGY PROFILE WORKSHEET 2-B

Energy Use Summary (in MBTUs)

Building EAST BASE

Month	19 79	19 80	19	19
January	3,159	3,139		
February	3,066	2,350		
March	2,155	2,847		
April	1,514	1,887		
May	1,196	1,486		
June	1,145	1,798		
July	1,725	1,666		
August	1,612	1,651		
September	2,259	1,776		
October	3,528	1,967		
November	3,060	2,151		
December	3,340	2,685		
Annual Totals	27,759 MBTUs	25,403 MBTUs		

ENERGY PROFILE WORKSHEET 3-A

Proportion of Energy Use By Source

Building EAST BASE

Year 1980 Total Annual Energy used 25,403 MBTU

ELECTRICITY 8,026 MBTU	NATURAL GAS 17,377 MBTU
Proportion of Total 31.6 %	Proportion of Total 68.4 %
ENERGY USES:	ENERGY USES:
1. LIGHTING	1. HEATING
2. HVAC EQUIPMENT	2. HOT WATER
3. AIR COMPRESSORS	3. STEAM CLEANING
4. COOLING	4.
5. MISCELLANEOUS	5.
OIL	**PURCHASED STEAM**
Proportion of Total _____ %	Proportion of Total _____ %
ENERGY USES:	ENERGY USES:
1.	1.
2.	2.
3.	3.
4.	4.
5.	5.

ENERGY PROFILE WORKSHEET 4-A

Electrical Energy Consumption: Lighting

Building EAST BASE Date Completed AUGUST, 1981

A	B	C	D	E	F	G
Location	Fixture Description	Number of Fixtures	Electrical Load Per Fixture (In Watts)	Total Electrical Load (In Watts)	Operating Hours/Year	Annual Electrical Use (In KWH)
INSPECTION PITS	TYPE 1	52	393 W	20,436	8,760	179,019
	TYPE 2	6	230 W	1,380		12,089
	TYPE 12	24	96 W	2,304		20,183
	TYPE 8	2	96 W	192		1,682
CHASSIS SHOP	TYPE 1	101	393 W	39,693		347,710
	TYPE 2	12	230 W	2,760		24,178
BODY SHOP	TYPE 1	18	393 W	7,074		61,968
	TYPE 2	2	230 W	460		4,030
	TYPE 4	3	150 W	450		3,942
	TYPE 13	7	253 W	1,771		15,514
	TYPE 8	1	96 W	96		841
YARD LIGHTS	250/HPS	27	310 W	8,370	4,380	36,661
	400/HPS	14	465 W	6,510		28,514
	100/MV	2	135 W	270		1,183
LOCKER ROOM	TYPE 27	12	96 W	1,152	8,760	10,092
	TYPE 35	12	96 W	1,152		10,092
					Total KWH	757,698

Column E = C × D

Column G = $\frac{E \times F}{1,000}$

ENERGY PROFILE WORKSHEET 4-B

Electrical Energy Consumption: HVAC Equipment

Building EAST BASE: MAINTENANCE BUILDING Date Completed AUGUST, 1981

A	B	C	D	E	F	G	H	I	J
Location	Equipment Description	Rated Load In HP	Operating Amps	Maximum Rated Amps	Load Factor	Estimated Load (in KW)	Number of Devices	Operating Hours Per Year	Annual Electrical Use (in KWH)
SUPPLY	MPHV-1	7.5			.75	5.6	1	8,760	49,056
	MPHV-2	20				15	1		131,400
	MPHV-3	7.5				5.6	1		49,056
	MPHV-4	5				3.75	1		32,850
	MPHV-5	5				3.75	1		32,850
	MPHV-6	5				3.75	1		32,850
	MPHV-7	5				3.75	1		32,850
	MPHV-8	.5				.375	1		3,285
	MPHV-9	1				.75	1		6,570
PUMPS	OP-1	1.5				1.13	1	2,500	2,825
	OP-2	3				2.25	1		5,625
	OP-3	1.5				1.13	1		2,825
EXHAUST	ME-1	2				1.5	1	8,760	13,140
	ME-2	2				1.5	1		13,140
	ME-3	5				3.75	1		32,850
	ME-4	7.5				5.6			49,056
								Total KWH	490,228

Column F = Column D ÷ Column E
Column G = Column C × Column F
Column I = Columns G × H × I

ENERGY PROFILE WORKSHEET 4-C

Electrical Energy Consumption: Miscellaneous Equipment

Building EAST BASE: MAINTENANCE Date Completed AUGUST, 1981

A	B	C	D	E	F	G	H	I	J
Location	Equipment Description	Rated Load In HP	Operating Amps	Maximum Rated Amps	Load Factor	Estimated Load (in KW)	Number of Devices	Operating Hours Per Year	Annual Electrical Use (in KWH)
SHOP	COMP #1	60			.75	45	1	1,000	45,000
"	COMP #2	60			"	45	1	"	45,000
"	COMP #3	20			"	15	1	"	15,000
								Total KWH	105,000

Column F = Column D ÷ Column E
Column G = Column C × Column F
Column I = Columns G × H × I

ENERGY PROFILE WORKSHEET 4-D

Heating Consumption

page 1 of 2

Building EAST BASE / MNT BLDG Date Completed August, 1981

ROOM NO.	ROOM NAME	TR			
		64	MAINTENANCE		
TRANSMISSION LOSS				TD-HRS	BTU×10⁶
ITEM	U	A	U×A		
ROOF	0.17	50,432	8573.4		
	1.20	1,088	1305.6		
GROSS WALL					
GLASS	1.13	64	92.3		
DOORS	1.13	4380	4949.4		
NET WALL	0.67	16,691	11,183.0		
PERIMETER FLOOR					
	F_2	P	F_2×P		
	.60	964	578.4		
INFILTRATION					
ITEM	K	CFH	K×CFH		
WINDOWS	.018				
DOORS		52,500	945		
WALLS					
SUB-TOTAL			27,607.1	112,057	3,093.6
OSA/MAKE-UP AIR					
	K	CFM	K×CFM		
SUB-TOTAL *.75x	1.08	110,440	89,466.4	112,057	10,024.2
				TOTAL MBTUs	13,117.8

* ASSUMES MAKE-UP AIR IS REQUIRED 75% OF THE FULL YEAR.

CORRECTION FOR SYSTEM EFFICIENCY:

$$\frac{\text{TOTAL MBTUs}}{\text{SYSTEM EFFICIENCY*}} = \text{ADJUSTED TOTAL MBTUs}$$

* System Efficiency = 1.0 For Direct Electrical Resistance Heat, 0.8 For Gas or Oil Fired Systems.

$$\frac{13,117.8}{.8} = 16,397.3 \text{ MBTUs}$$

ENERGY PROFILE WORKSHEET 4-D

Heating Consumption

Building EAST BASE / MNT BLDG Date Completed AUGUST, 1981

ROOM NO.	ROOM NAME	TR	OPERATIONS		
		68			

TRANSMISSION LOSS				TD-HRS	BTU×10⁶
ITEM	U	A	U×A		
ROOF	0.094	7650	719.1		
GROSS WALL					
GLASS	1.13	1110	1254.3		
DOORS					
NET WALL	0.118	6390	752.04		
PERIMETER FLOOR					
	F_2	P	F_2×P		
	.60	385	231.0		
INFILTRATION					
ITEM	K	CFH	K×CFH		
WINDOWS	.018				
DOORS					
WALLS					
			2956.44	143,020	422.8
OSA/MAKE-UP AIR					
	K	CFM	K×CFM		
	1.08				Neglectable
				TOTAL MBTUs	422.8

CORRECTION FOR SYSTEM EFFICIENCY:

$$\frac{\text{TOTAL MBTUs}}{\text{SYSTEM EFFICIENCY*}} = \text{ADJUSTED TOTAL MBTUs}$$

* System Efficiency = 1.0 For Direct Electrical Resistance Heat, 0.8 For Gas or Oil Fired Systems.

$$\frac{422.8}{.8} = 528.5 \text{ MBTUs}$$

ENERGY CONSUMPTION SUMMARY:

EAST BASE - 1980

Electricity:	
Lighting	3,656 MBTU
HVAC Equipment	3,216 MBTU
Miscellaneous Equipment	371 MBTU
*Cooling/Miscellaneous Power	837 MBTU
Total Consumption	8,026 MBTU
Natural Gas:	
Transmission/Infiltration (Maintenance Building)	3,867.0 MBTU
Transmission/Infiltration (Operations Building)	528.5 MBTU
OSA/Make-Up Air	12,530.3 MBTU
*Steam Cleaning/Domestic Hot Water	451.2 MBTU
Total Consumption	17,377.0 MBTU

* Estimates for these items were calculated by subtracting the total of the items powered by electricity or natural gas from the respective total energy consumed, as reported by utility bills and shown on worksheet 2-A.

APPENDIX E:

RESISTANCE FACTORS OF COMMON BUILDING MATERIALS

SOURCE: WASHINGTON STATE ENERGY CODE

INSULATION

2" - 2 1/2" Batt	R-7.00
3" - 3 1/2" Batt	R-11.00
5 1/2" - 6 1/2" Batt	R-19.00
7 3/4" - 8 1/4" Batt	R-24.00
Rigid preformed roof insulation for use above deck	R=2.78 per inch

Board and Slab Insulation

Cellular glass	R=2.50 per inch
Glass fiber, organic bonded	R=4.00 per inch
Expanded polystyrene extruded, plain	R=4.00 per inch
Expanded polystyrene extruded	R=5.00 per inch
Expanded polystyrene, molded beads	R=3.57 per inch
Expanded polyurethane	R=6.25 per inch
Mineral fiber w/resin binder	R=3.45 per inch
Mineral fiberboard wet felted	R=2.94 per inch
Mineral fiberboard wet molded	R=2.38 per inch
Acoustical tile	R=2.78 per inch
Wood shredded and cemented in preformed slabs	R=1.67 per inch

Loose Fill Insulation

Mineral fiber (rock, slag or glass)	
3"	R=9.00
4 1/2"	R=13.00
6 1/2"	R=19.00
7 1/4"	R=24.00
Cellulose (milled paper or wood pulp) insulation	R=3.70 per inch
Sawdust or shavings	R=2.22 per inch
Wood fiber, softwoods	R=3.33 per inch
Perlite (expanded)	R=2.70 per inch
Vermiculite (expanded)	R=2.20 per inch

Foam

Ureaformaldahyde	R=4.0-5.5 per inch depending on manufacturer

WOOD

Maple, oak and similar hardwoods	R=0.91 per inch
Fir, pine and similar softwoods	R=1.25 per inch
Plywood	R=1.24 per inch

Hardboard

Medium density 40#/ft^3	R=1.37 per inch
High density, service tempered 50#/ft^3	R=1.06 per inch
High density, standard tempered	R=1.00 per inch

Particleboard

Low density 37#/ft^3	R=1.85 per inch
Medium density 50#/ft^3	R=1.06 per inch
High density 62.5#/ft^3	R=0.85 per inch

BUILDING BOARDS AND SIDING

Asbestos - cement board	R=0.25 per inch
Cyp board	R=0.90 per inch

Insulating Board

Sheathing 18#/ft^3	R=2.64 per inch
Nail-base sheathing 25#/ft^3	R=2.28 per inch
Sound deadening board	R=2.70 per inch
Laminated paperboard	R=2.00 per inch

Building Paper

Vapor-permeable felt	R=0.06
Vapor-seal, 2 layers of mopped 15# felt	R=0.12
Vapor-seal, plastic	R=zero

Siding Materials

Shingles

Asbestos-cement	R=0.21
Wood, 16 inch, 7-1/2 exposure	R=0.87
Wood, double, 16-inch, 12inch, exposure	R=1.19
Wood, plus insul. backer board. 5/16 inch	R=1.40

Siding

Asbestos-cement, 1/4 inch, lapped	R=0.21
Asphalt roll siding	R=0.16
Asphalt insulating siding (1/2 inch board)	R=1.46
Wood drop, 1 x 8 inch	R=0.79
Wood, bevel, 1/2 x 8 inch, lapped	R=0.81
Wood, bevel, 3/4 x 10 inch, lapped	R=1.05
Wood, plywood, 3/8 inch, lapped	R=0.59
Aluminum or steel, over sheathing hollow-backed	R=0.61
Insulating-board backed nominal 3/8 inch	R=1.82
Insulating-board backed nominal 3/8 inch foil backed	R=2.96

Architectural glass	R=0.10

MASONRY MATERIALS

Adobe 10" thick			R=2.78
Adobe 14" thick			R=3.89
Common brick			R=0.20 per inch
Face brick			R=0.11 per inch
Stone (either sandstone or limestone)			R=0.08 per inch
Stucco			R=0.20 per inch
Plaster			R=0.20 per inch
Concrete		Density	
Sand & gravel concrete			R=0.08 per inch
Cement mortar		116	R=0.20 per inch
Gypsum-fiber concrete 87-1/2% gypsum, 12-1/2% wood chips		51	R=0.60 per inch
Lightweight aggregates including expanded shale, clay or slate; expanded slags; cinders; pumice; vermiculite; also cellular concretes		120	R=0.19 per inch
		100	R=0.28 per inch
		80	R=0.40 per inch
		60	R=0.59 per inch
		40	R=0.86 per inch
		30	R=1.11 per inch
		20	R=1.43 per inch
Perlite		40	R=1.08 per inch
		30	R=1.41 per inch
		20	R=2.00 per inch
Concrete blocks, three oval core:			
Sand and gravel aggregate	4 inch	75	R=0.71
	8 inch	75	R=1.11
	12 inch	75	R=1.28
Cinder aggregate	3 inch	75	R=0.86
	4 inch	75	R=1.11
	8 inch	75	R=1.72
	10 inch	75	R=1.80
	12 inch	75	R=1.89
Lightweight aggregate (expanded shale, clay, slate or slag; pumice)	3 inch	75	R=1.27
	4 inch	75	R=1.50
	8 inch	75	R=2.00
	12 inch	75	R=2.27
Plaster			
Cement, sand aggregate plaster			R=0.20 per inch
Gypsum plaster			R=0.64 per inch
Perlite aggregate			R=0.67 per inch
Vermiculite aggregate			R=0.59 per inch

ROOFING MATERIALS

Asbestos-cement shingles	R=0.21
Asphalt roll roofing	R=0.15
Asphalt shingles	R=0.44
Slate 1/2 inch thick	R=0.05
Built-up roofing	R=0.33

SURFACE AIR FILMS

Inside (still air)

Heat flow UP (through horizontal surface)

Non-reflective	R=0.61
Reflective	R=1.32

Heat flow DOWN (through horizontal surface)

Non-reflective	R=0.92
Reflective	R=4.55

Heat flow HORIZONTAL (through vertical surface)

Non-reflective	R=0.68

Outside

Heat flow any direction surface any position 15 mph wind	R=0.17

AIR SPACES	3/4 inch	4 inch
Heat flow UP		
Non-reflective	R=0.87	R=0.94
Reflective, one surface	R=2.23	R=2.73
Heat flow DOWN		
Non-reflective	R=1.02	R=1.23
Reflective, one surface	R=3.55	R=8.94
Heat flow HORIZONTAL		
Non-reflective	R=1.01	R=1.01
Reflective, one surface	R=3.48	R=3.45

Note: The addition of a second reflective surface facing the first reflective surface increases thermal resistance values of an air space only 4 to 7 percent.

GLASS

Single glass	U=1.13
Double glass 1/4 inch air space	U=0.65
Double glass 1/2 inch air space	U=0.58
Storm windows 1 inch to 4 inch air space	U=0.56
Glass block	U=0.54
Single plastic sheet	U=1.09
Skylights - single glass	U=1.22

DOORS

Solid wood	
1 inch thick	U=0.64
1-1/4 inch thick	U=0.55
1-3/8 inch thick	U=0.53
1-1/2 inch thick	U=0.49
1-3/4 inch thick	U=0.48
2 inches thick	U=0.43
Steel doors over 3 spaces	
With mineral fiber core	U=0.59
With solid urethane foam core	U=0.40
With solid polystyrene core	U=0.47

SHADING COEFFICIENTS

Single glass	With Draperies	With Venetian Blinds
1/4 inch regular	0.95	0.64
1/2 inch regular	0.88	0.64
1/4 inch heat absorbing	0.67	0.57
3/8 inch heat absorbing	0.57	0.54
1/2 inch heat absorbing	0.50	0.42
Reflective coated glass	0.60	0.50
(see manufacturer's literature	0.50	0.42
for exact values.)	0.40	0.33
	0.30	0.25

FINISH FLOORING MATERIALS

Asphalt, linoleum, vinyl, or rubber tile	R=0.05
Cork tile	R=0.28
Carpet with fibrous pad	R=2.08
Carpet with rubber pad	R=1.23

HEAT LOSS OF CONCRETE FLOORS AT OR NEAR *

GRADE LEVEL PER FOOT OF EXPOSED EDGE

Outdoor Design Temperature, F	Heat Loss per Foot of Exposed Edge, Btuh: Recommended 2-inch Edge Insulation	Heat Loss per Foot of Exposed Edge, Btuh: 1-inch Edge Insulation
-20 to -30	.50	.55
-10 to -20	.45	.50
0 to -10	.40	.45

Outdoor Design Temperature, F	1-inch Edge Insulation	No Edge Insulation[2]
-20 to -30	.60	.75
-10 to -20	.55	.65
0 to -10	.50	.60

[2] This construction not recommended; shown for comparison only.

*American Society of Heating, Refrigerating and Air Conditioning Engineers

APPENDIX F: LIGHTING LEVELS AND EFFICIENCIES

SOURCE: ENERGY MANAGEMENT WORKBOOK, Seattle City Light

LIGHTING LEVEL RECOMMENDATIONS*

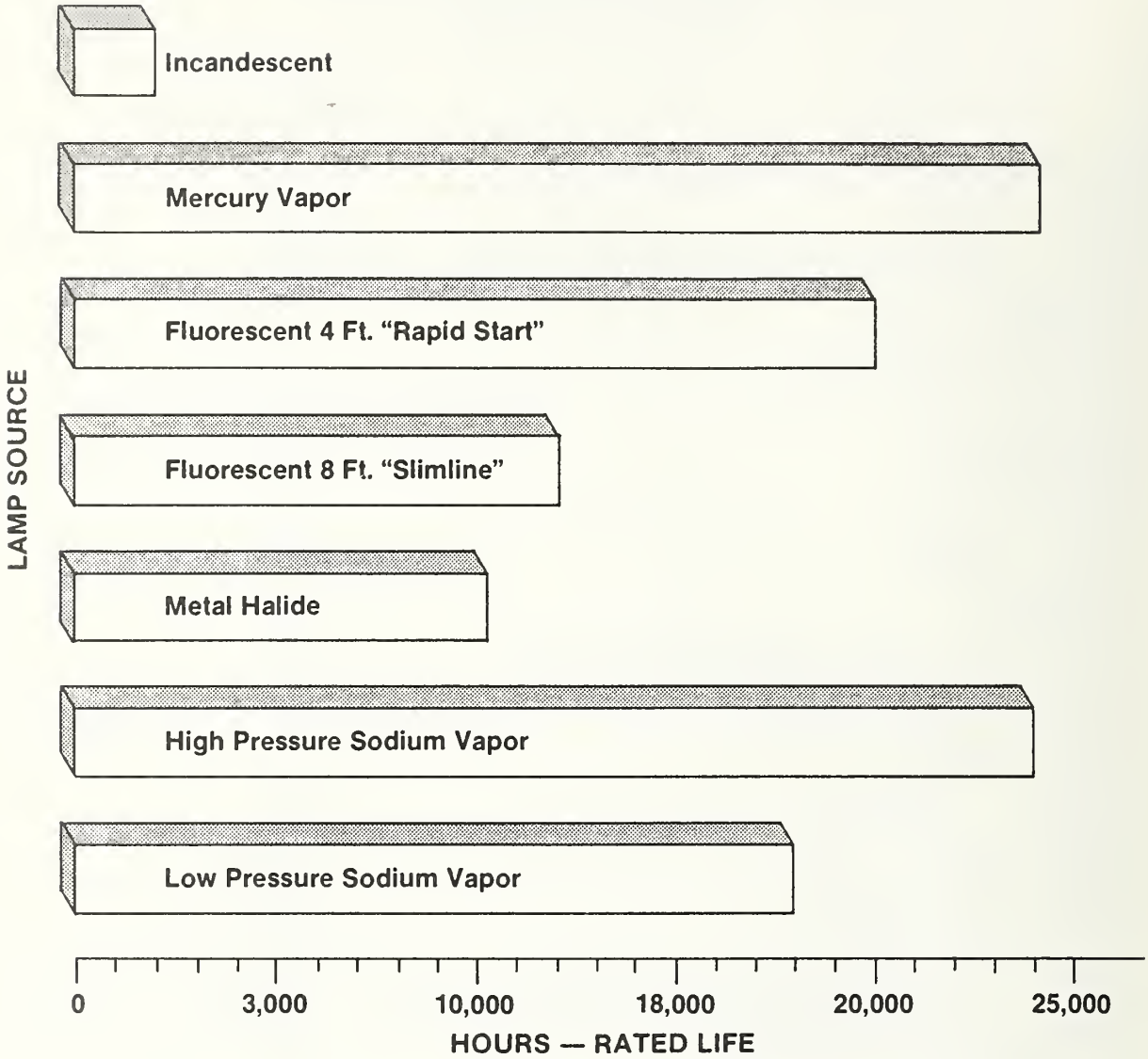
(Values in footcandles)

Type of Work	Recommended
Assembly Work	
Rough	30
Medium	100
Fine	500
Bakeries	30
Chemical Works	30
Construction—Indoor	—
Construction—Outdoor	—
Elevators	10 ± 5
Laundries	30
Machine Shops	
Rough	50
Medium	100
Fine	500
Offices	
Bookkeeping, Typing and Accounting	100
Business Machine and Keypunch	75 ± 15
Conference Room	30
Drafting	
Detail	100
Sketching	100
Filing	30 ± 5
Lobby/Corridors	10 ± 5
Mail Sorting	50
Stenographic	50
Reading Handwriting in Hard pencil	75 ± 15
Reading Handwriting in Ink or Medium Pencil	50 ± 10
Schools (Typical Classroom)	50
Power Plants	30
Printing Shops	30
Warehouses	10-30
Welding	50
Woodworking	
Rough	30
Medium	50
Fine	100

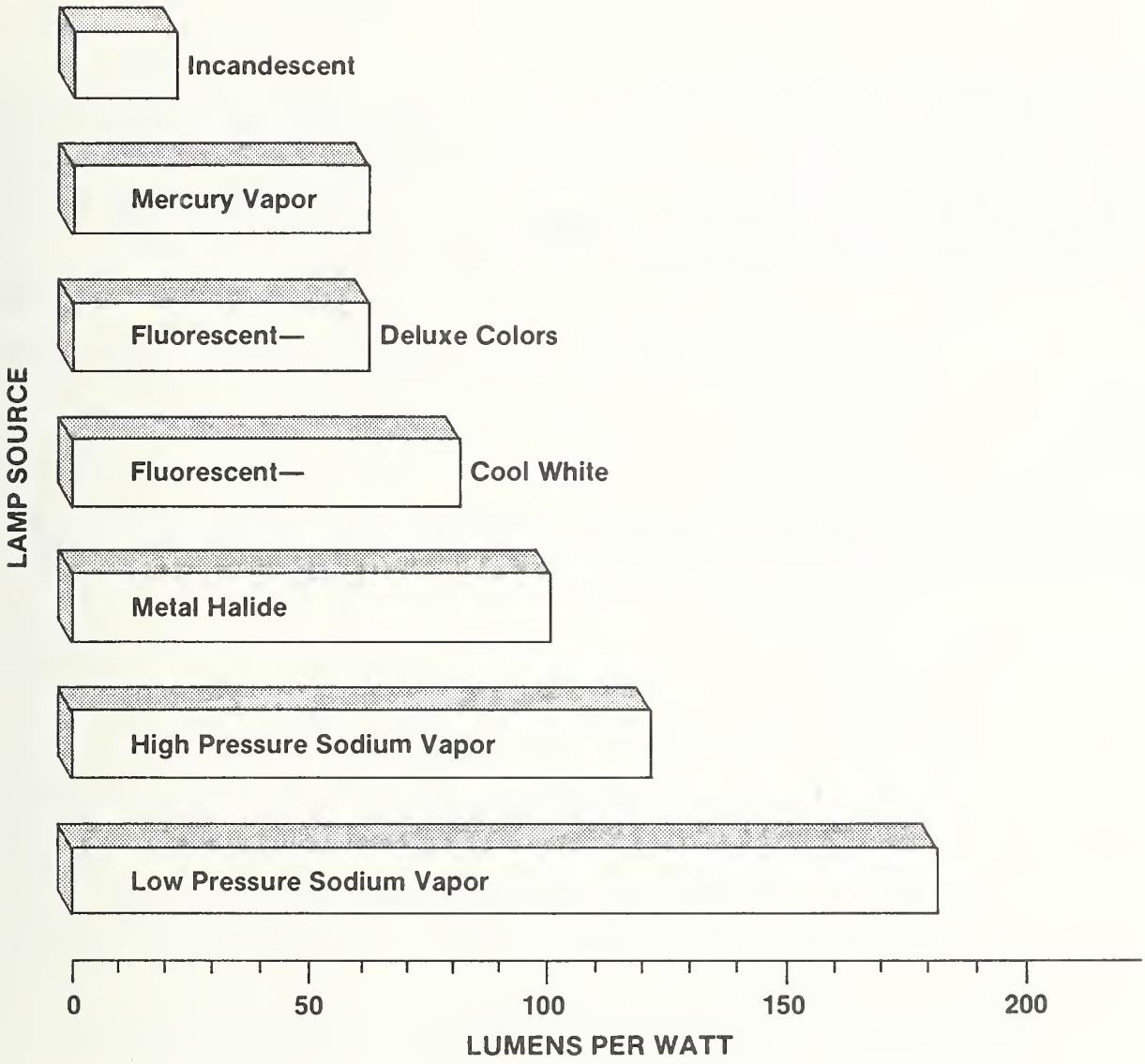
**Recommended by the Federal Energy Administration (now Department of Energy).*

Task lighting for specific stations should be observed. The idea is not to provide lighting for entire room at 100 foot-candles when the drafting table, for example, is the only location that needs it.

Rated Life of Various Light Sources



Efficiencies of Various Light Sources



APPENDIX G: SAMPLE HEAT LOSS CALCULATION FOR SERVICE DOORS

SAMPLE HEAT LOSS CALCULATION FOR SERVICE DOORS

Problem

The maintenance building has 19 large overhead service doors that provide access to maintenance pits and repair areas. These doors are frequently left open during working hours while the heating system is operated. It is suspected that this practice is a major factor in the building's heat loss. The purpose of this analysis is to estimate the heat lost through open service doors.

Existing Conditions

Total area of each door: 228 feet^2 (19 feet x 12 feet)

Estimated velocity of infiltration: 150 ft/min.

Temperature difference: 20°F *

* Based on estimate of median annual TD from BIN data for Seattle, Washington, for 24-hour building heated to an average indoor temperature of 64°F.

Analysis

$$Q = .018 \times CFH \times TD$$

$$F = A \times V = 228\ ft^3 \times 150\ ft/min.$$

$$CHF = F \times 60 = 2{,}052{,}000\ ft^3/hour/door$$

$$Q = .018 \times 2{,}052{,}000\ ft^3/hour\ per\ door \times 20^oF$$

$$Q = 738{,}720\ BTUs/hour\ for\ each\ open\ door$$

$$Q\ (corrected\ for\ system\ efficiency) = \frac{738{,}720\ BTUs}{0.8} = 923{,}400\ BTUs/hour$$

Conclusion

Assuming the price of natural gas is $0.32/therm, it is estimated that for each full hour that each door is left open, about $3.00 worth of natural gas (9.2 therms x $0.32) is unnecessarily lost. This cost is substantial and can be reduced by instituting an employee awareness program to keep doors closed or by considering other options, like radiant heating, automatic door closures, air curtains and plastic strips.

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